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HP-9810A CALCULATOR PROGRAMS FOR PLOTTING THE 2-DIMENSIONAL MOTION OF CYLINDRICAL PAYLOADS RELATIVE TO THE SHUTTLE ORBITER

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CONTENTS

		Page
1.	INTRODUCTION	1
2.	SETTING PLOT BOUNDARIES	3
	2.1 Physical Boundaries	3
	2.2 Logical Boundaries	5
	2.3 Relation Between Logical and Physical Boundaries	5
3.	ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)	7
4.	PAYLOAD MOTION PLOT PROGRAM (PMPP)	9
	4.1 Input Data	9
	4.2 State Vector Propagation	14
	4.2.1 Rotational Motion	14
	4.2.2 Differential Drag Acceleration	15
	4.2.3 Translational Motion	16
	4.3 Transformation from Payload Body to Orbiter Body Coordinates	22
	REFERENCES	24
	APPENDIX A: OSEPP/PMPP OPERATING INSTRUCTIONS	A-1
	APPENDIX B: OSEPP CODE	B-1
	APPENDIX C: PMPP CODE	C-1

FIGURES

		Page
Figure 1.	Typical OSEPP/PMPP Display	2
Figure 2.	Physical Plot Boundaries	4
Figure 3.	Dynamic Pressure Profile	11
Figure 4.	Local Vertical Coordinate System	12
Figure 5.	Rotation of Coordinates	19
Figure 6.	Transformation from Payload Body to Orbiter Body Coordinates	23

1. INTRODUCTION

The HP-9810A calculator programs to be described here provide the capability to generate HP-9862A plotter displays, such as that illustrated in Figure 1, which depict the apparent motion of a free-flying cylindrical payload relative to the Shuttle Orbiter body axes by projecting the payload geometry into the Orbiter plane of symmetry at regular time intervals. As modeled in these programs, the apparent motion is affected by

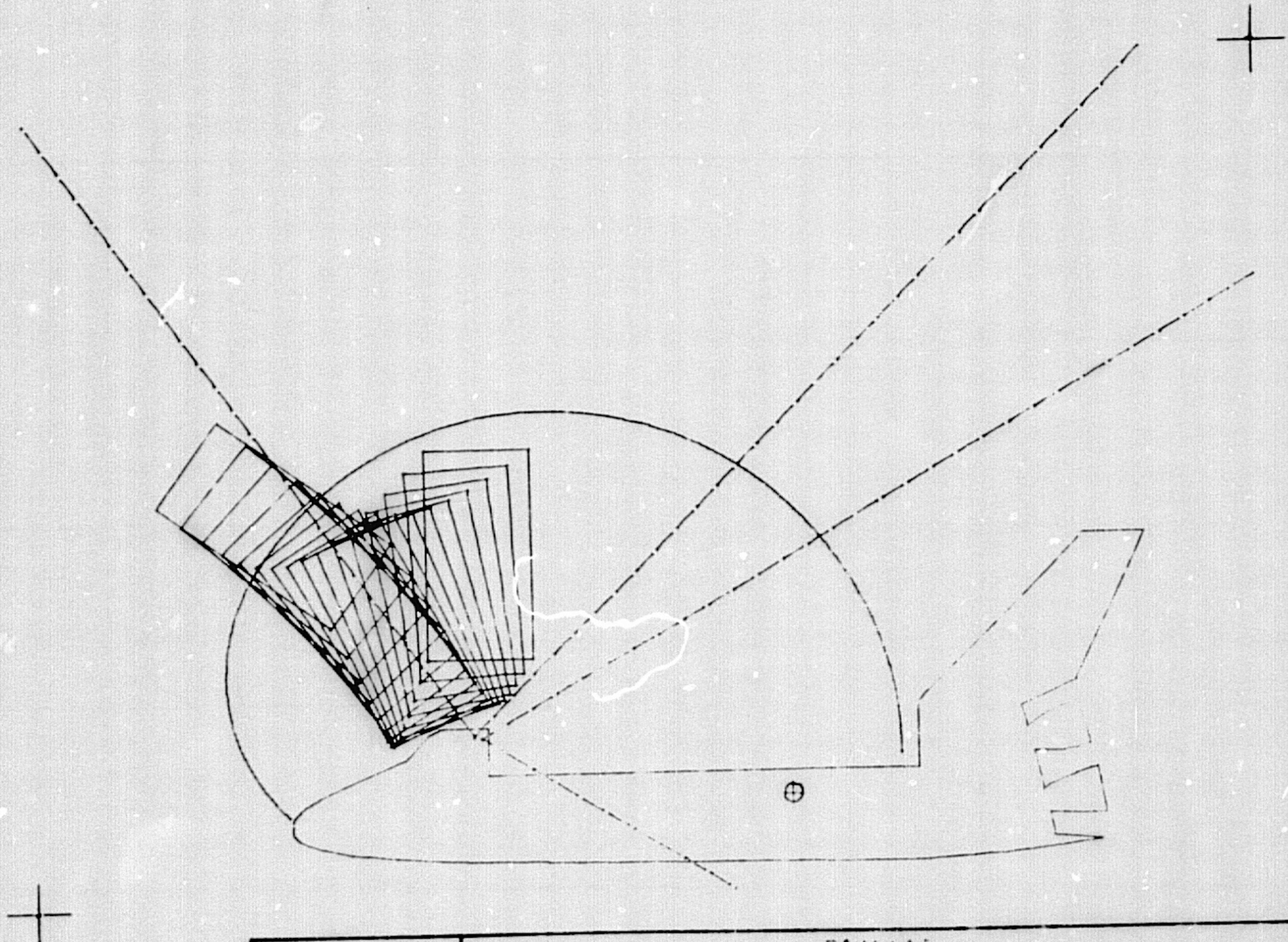
a) initial position and velocity of the payload center of gravity (CG) relative to the Orbiter CG,

b) pitch rates and initial pitch angles of the payload and of the Orbiter, and

c) translational accelerations resulting from aerodynamic drag forces which act separately on the payload and the Orbiter and vary as functions of their pitch angles.

The current program configuration allows each vehicle only one degree of rotational freedom: pitching at a constant rate about an axis normal to the Shuttle's orbit plane. Yaw and roll angles for both vehicles are constrained to be zero.

Because of limitations on the number of instructions that can be stored in HP-9810A memory, two programs must be executed sequentially to generate a display such as that shown in Figure 1. The Orbiter Side Elevation Plot Program (OSEPP) generates the side elevation view of the Orbiter vehicle. At the user's option, this program will also plot the approximate reach envelope of the Remote Manipulator System (RMS), the RMS operator's fields of view through the overhead and cargo bay windows, and/or the field of view through the Crew Optical Alignment Sight (COAS). The Payload Motion Plot Program (PMPP), after prompting the user for necessary input data, calculates the angular and translational motion of the payload relative to the Orbiter and plots the payload position at regular time intervals. Engineering descriptions of the OSEPP and the PMPP are contained in Sections 3 and 4. Specific operating instructions for the two programs are contained in Appendix A. General instructions for operating the HP-9810A calculator and the HP-9862A plotter are contained in References 1 and 2.



		ORBITER		PAYLOAD							
ALT (NM)	270	W (LB)	185,000	L (FT)	30	W (LB)	12,000	X_0 (FT)	44	$\dot{X}_0$ (FPS)	0
Δt (MIS)	1.00	α_a (DEG)	0	D (FT)	15	α_p (DEG)	90	Y_0 (FT)	0	$\dot{Y}_0$ (FPS)	0
t_{STOP} (MIS)	15.00	$\dot{\alpha}$ (DEG/SEC)	.06	C_D	2.2	$\dot{\alpha}$ (DEG/SEC)	0	Z_0 (FT)	-35	$\dot{Z}_0$ (FPS)	0

Figure 1. Typical OSEPP/PMPP Display

2. SETTING PLOT BOUNDARIES

2.1 PHYSICAL BOUNDARIES

The HP-9862A plotting board is a rectangle whose dimensions are approximately 17 inches by 12 inches. The plotter X axis is parallel to the longer side and the Y axis is parallel to the shorter side. The maximum area accessible to the plotter's inking pen is a smaller rectangle whose dimensions are 15 inches by 10 inches. A plot can be drawn on any sheet of paper small enough to fit on the plotting board. The paper is held in place by electrostatic force that is controlled by the "CHART HOLD" button on the plotter control panel. As indicated in Figure 2, a small sheet of paper can be located at an arbitrary position on the board, and the plotting area can be bounded on the paper by a simple procedure that is described in the next paragraph.

For convenience, fiducial marks should be inscribed on the sheet of plotting paper at the lower left and upper right corners of the desired plotting area before it is placed on the plotting board. After the paper has been secured by pressing the "CHART HOLD" button, the user presses the "PEN UP" and then the "LOWER LEFT" buttons on the plotter control panel. After the pen comes to rest, its position is adjusted to coincide with the lower left corner of the desired plotting area by rotating two knobs adjacent to the "LOWER LEFT" button. These two knobs move the pen parallel to the plotter X and Y axes independently. After the pen point has been positioned over the lower left fiducial mark as closely as the eye can judge, the "PEN DOWN" and "PEN UP" buttons can be pressed in sequence to mark the exact pen position on the paper. If necessary, fine adjustments of the pen position can then be made. After the user has adjusted the pen position at the lower left corner to his satisfaction, he presses the "UPPER RIGHT" button and positions the pen over the upper right fiducial mark by using the adjacent control knobs. Again, the exact position of the pen can be determined by pressing the "PEN DOWN" and "PEN UP" buttons in succession to produce a dot of ink on the paper.

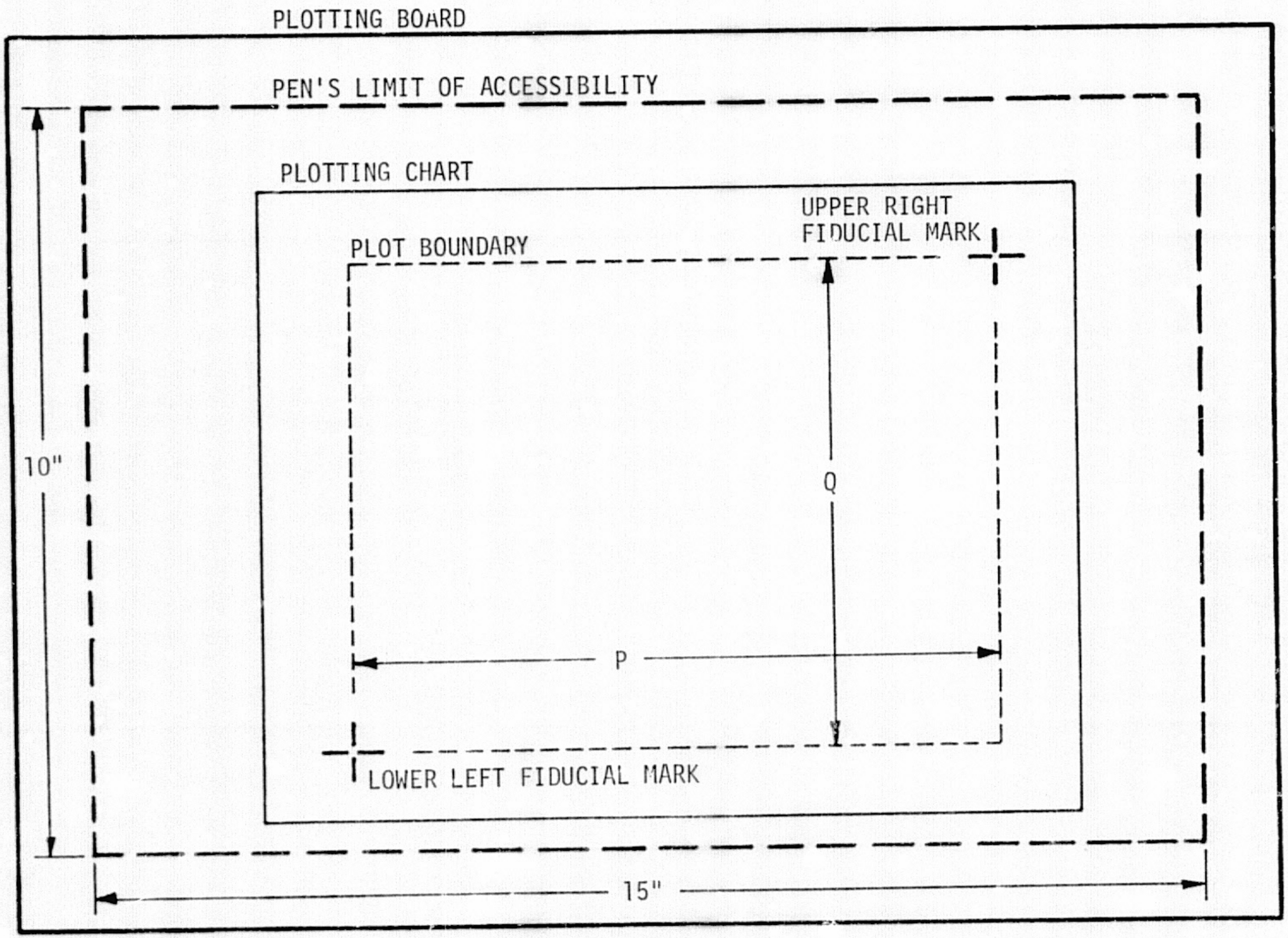


Figure 2. Physical Plot Boundaries

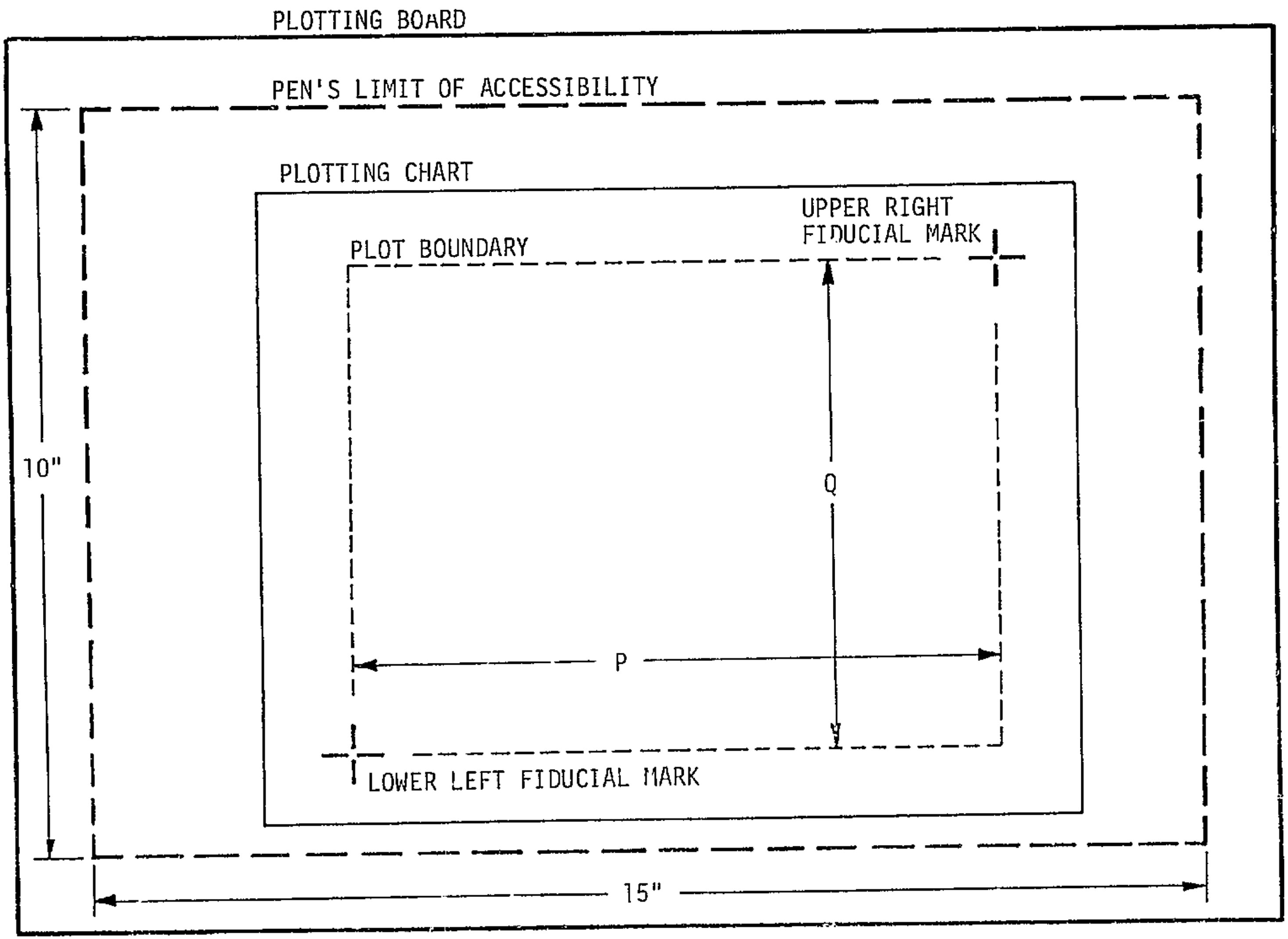


Figure 2. Physical Plot Boundaries

The sequence of operations described in the preceding paragraph is important. The adjustment of the lower left corner must always be made first. If for any reason a readjustment is made at the lower left corner, it must be followed by a readjustment at the upper right corner.

2.2 LOGICAL BOUNDARIES

OSEPP and PMPP both utilize the plotter scaling function of the HP-9810A Math Block Read-Only Memory (ROM) package. The scaling function is described on pages 2-15 through 2-20 of Reference 3. The plotted figures are composed of straight line segments drawn between points whose logical coordinates are measured in inches relative to the Orbiter Structural Body Coordinate System. This system is described in Figure 23 of Reference 4. To avoid confusion with the local vertical coordinates which are used to describe the trajectory of the payload, the X_0 and Z_0 axes of Reference 4 are designated U and V, respectively, in the user instructions contained in Appendix A. The U and V axes correspond to the X and Y axes of the HP-9862 A plotter.

The user controls the scale and the location of the figures within the physical boundaries of the plotting area by loading appropriate values for the logical plotting boundaries (U_{min}, U_{max}, V_{min}, and V_{max}) into data registers 001 through 004 of the HP-9810A calculator. Once loaded, the logical boundaries need not be reloaded (so long as the calculator power switch remains on) unless it is desired to change the scale or translate the position of the Orbiter within the physical boundaries of the plotting area.

During the execution of either program, if the calculator finds that either end of any line segment lies outside the established plotting boundary, then that particular segment will not be plotted. Program execution will continue normally in all other respects, and any subsequent line segments that lie entirely within the boundaries will be plotted correctly.

2.3 RELATION BETWEEN LOGICAL AND PHYSICAL BOUNDARIES

The Math Block scaling function automatically equates the logical boundaries stored in data registers 001 through 004 to the physical boundaries

established by the procedure described in Section 2.1. To avoid distortion of the plotted figures, it is necessary that

$$\frac{P}{Q} = \frac{U_{max} - U_{min}}{V_{max} - V_{min}} , \tag{1}$$

where P and Q represent the actual physical distances (measured parallel to the plotter X and Y axes, respectively) between the lower left and upper right fiducial marks on the plotting paper.

3. ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

Appendix B contains a listing of the OSEPP code. The basic figure generated by the program is a side view of the Orbiter profile, with the cargo bay doors open. In general, the coordinates are stored in the instruction registers rather than the data registers. Coordinates were obtained from References 5 and 6. In cases where coordinates could not be derived from tabulated dimensions, they were scaled from engineering drawings. The Orbiter CG, which is designated by a cross inscribed within a circle, was taken to be located longitudinally at U = 1093 inches and vertically at V = 380 inches. The longitudinal position is the mean of the forward and aft limits which are specified in Figure 2.1-6 of Reference 5. The vertical position was scaled from the aforementioned figure.

Circular arcs, where appropriate, are approximated by a series of chords that are generated by a subroutine which is identified by the label C*. The subroutine is described by steps 1500 through 1606 in the program listing. Before calling this subroutine, the main program stores the logical coordinates of the center of the circle, its radius, the limiting angles of the arc, and the number of chords to be drawn in data registers 051 through 056. If the plotter pen is to be <u>down</u> when it moves to the first calculated point on the circular arc, the SET FLAG key is activated before calling the subroutine. If the plotter pen is to be <u>up</u> during its initial translation, the CLEAR key is activated† to clear the flag before calling the subroutine.

At the user's option, dashed rays may be drawn on the plot to define the nominal limits of the RMS operator's fields of view. The rays are generated by another subroutine which is identified by the label D, and which is described by steps 1700 through 1784 of the program listing. Before

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*Individual keys on the HP-9810A keyboard will be designated by circumscribing the appropriate symbol as shown here.

†This also clears data registers a and b, along with all three display registers.

calling this subroutine, the main program stores the logical coordinates of the origin of the ray, the angle that the ray makes with the U axis, the total length of the ray, and the length of the individual dashes in data registers 061 through 065.

4. PAYLOAD MOTION PLOT PROGRAM (PMPP)

Appendix C contains a listing of the PMPP code. The first basic function performed by this program is to prompt the user for the necessary inputs and to store them in appropriate data registers for subsequent use. After the input operation is complete, the PMPP causes the HP-9862A plotter to plot the position and orientation of the payload relative to the Orbiter at user-specified time intervals.

4.1 INPUT DATA

The first input required by PMPP is the altitude of the Shuttle orbit. The program assumes the orbit to be circular; however, the calculations are valid (except possibly for drag effects) for noncircular orbits if the eccentricity is not too large. The input orbit altitude H is measured in nautical miles above the equatorial radius of the earth. The program calculates the orbit radius r (measured in feet) by the use of the equation

$$r = 6076.1\ (H + 3443.9) \quad . \tag{2}$$

The angular rate of the Orbiter CG about the center of the earth, relative to inertial space, is then computed from the equation

$$\omega = \sqrt{\mu/r^3} \quad , \tag{3}$$

where

$$\mu = 1.4076469 \times 10^{16}\ \mathrm{ft}^3/\mathrm{sec}^2 \quad . \tag{4}$$

The orbital rate ω is measured in radians per second, and is a basic constant in the Clohessy-Wiltshire equations that are detailed in Section 4.2.3.

After calculating ω, the program computes the dynamic pressure q (measured in $\mathrm{lb/ft}^2$) by using whichever of the three following equations is appropriate.

$$\text{IF} \quad H \leq 160: \quad q = \exp\ (-2.88 - .0485H) \quad . \tag{4a}$$

$$\text{IF } 160 < H \leq 380: \quad q = \exp(-5.61 - .03141H) \quad . \tag{4b}$$

$$\text{IF } 380 < H: \quad q = \exp(-10.87 - .01758H) \quad . \tag{4c}$$

The variation of q with altitude, as defined by Equations (4a) through (4c), is illustrated in Figure 3. This dynamic pressure profile was derived from the aerodynamic drag acceleration data contained in Figure 3-15 of Reference 6.

After calculating and storing q for future use, PMPP prompts the user for the weight W_S, initial pitch angle α_S, and the pitch rate $\dot{\alpha}_S$ of the Shuttle Orbiter. The pitch angle and the pitch rate are measured relative to a local vertical coordinate system. As illustrated in Figure 4, the local vertical Z axis is directed toward the center of the earth, the Y axis points in a direction opposite to that of the angular momentum vector of the orbit, and the X axis points in the downtrack direction, completing a right-hand orthogonal triad. Relative to inertial space, the local vertical system rotates about its -Y axis at the constant angular rate ω . The Orbiter pitch angle is measured from the horizontal plane to the Orbiter longitudinal (-U) axis, and is positive when the nose is pitched up.

It should be noted that when the input Orbiter pitch rate is zero, it will pitch at a rate of $-\omega$ with respect to inertial space due to the rotation of the local vertical coordinate system. If it is desired to apply a particular <u>inertial</u> rate to the Orbiter, it must be converted to a local vertical rate before inputting it to the program. This is accomplished by transferring ω from data register 020 to the bottom display register by the sequence of keystrokes X←( ) 0 2 0 , multiplying it by 57.2957795 to convert the angular units from radians to degrees, and then adding the result to the desired inertial rate (expressed in degrees per second).

The next items on the input data list are the payload's length ℓ, diameter d, drag coefficient C_D, weight W, initial pitch angle α , and pitch rate $\dot{\alpha}$. The payload is assumed to be cylindrical, and its pitch angle is measured from the local horizontal plane to the centerline of the cylinder. The notes in the preceding paragraph concerning the simulation of

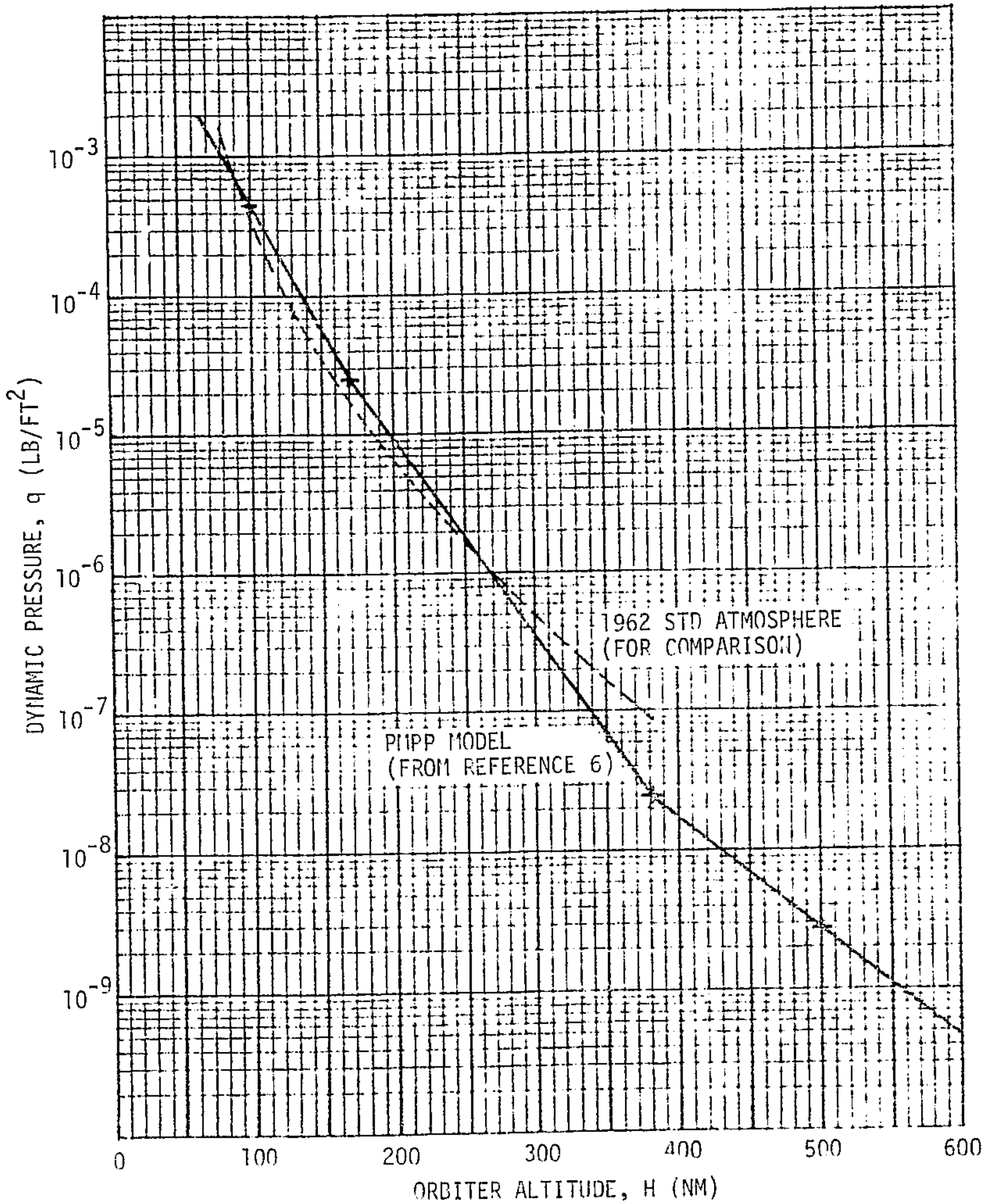

Figure 3. Dynamic Pressure Profile

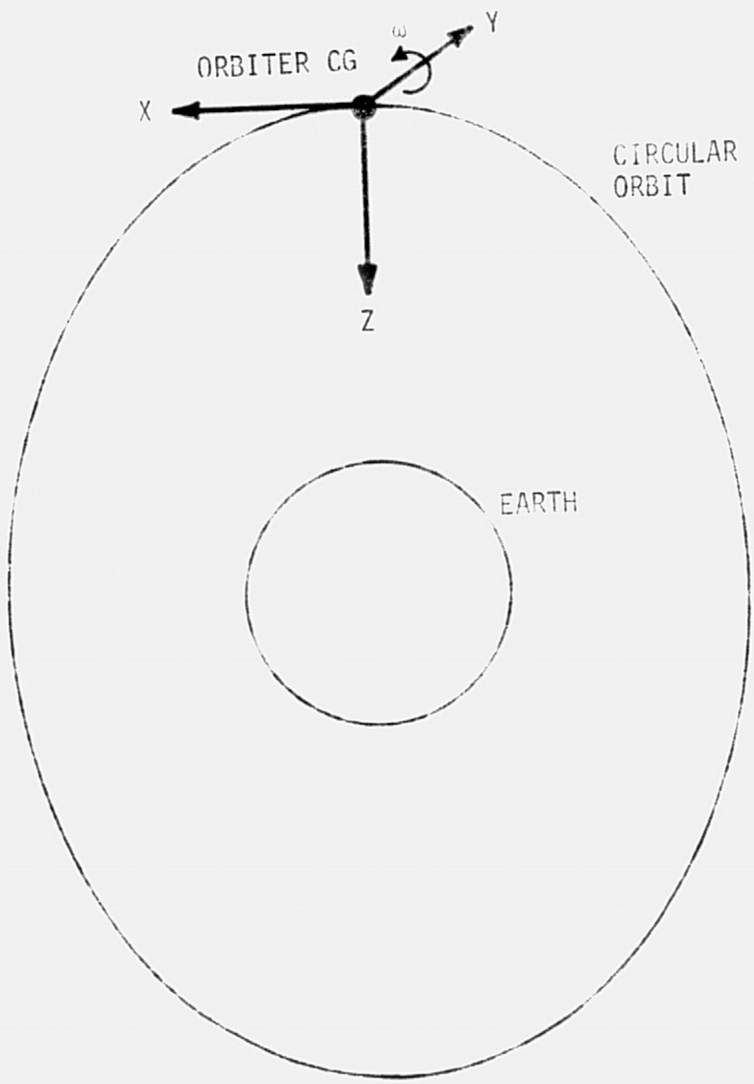

Figure 4. Local Vertical Coordinate System

inertial pitch rates apply to the payload as well as to the Orbiter. The payload drag coefficient is based on projected frontal area (which is calculated internally as a function of pitch angle) and normally it should be assigned a value between 2.0 and 2.2

After loading the quantities described above, the user is prompted for the initial state time and the position and velocity of the payload CG relative to the Orbiter CG. Time is input in hours, minutes, and seconds (reading from top to bottom in the HP-9810A display registers), then it is converted and stored internally in seconds. Relative position and relative velocity are expressed in terms of their components parallel to the X, Y, and Z axes (again reading from top to bottom in the display registers) of the rotating coordinate system illustrated in Figure 4. As previously noted in Section 3, the Orbiter CG is assumed to lie in the Orbiter's plane of symmetry at U = 1093 inches and V = 380 inches. The payload CG is assumed to lie at the centroid of the cylinder described in the preceding paragraph.

The last two input items are T_{STOP} (the state time at which the final payload position is to be plotted) and t (the interval between successive plots of payload position). After t is loaded and the CONTINUE key is depressed, the program proceeds automatically to plot the position of the payload at the specified time intervals (beginning with the initial input position) until T_{STOP} is reached.

During the input data loading process, the program prints a prompting message on paper tape for each necessary item of input and then stops to wait for the user to load the appropriate number(s) in the HP-9810A display register(s). After loading the desired value(s), the user presses the CONTINUE key to resume program execution. Each time before printing the prompting message, the program transfers the current stored value of the appropriate input variable into the display register(s). Often when plotting several related displays, certain input quantities will remain constant from run to run. In such cases, the user has only to press the CONTINUE key to duplicate the value from the previous run. When utilizing this feature of the program, the user should note that the values of time-dependent quantities (Orbiter and payload pitch angles, the state time, and the relative position and velocity of the payload) that are displayed after the prompting message

will correspond to the <u>end</u> rather than the <u>beginning</u> of the previous run. This permits the plotting of a sequence of payload positions to be resumed at the final position of the previous run simply by advancing T_{STOP} in a subsequent run. However, it means that the values of the time-dependent variables must be reloaded if it is desired to start afresh with the initial conditions.

4.2 STATE VECTOR PROPAGATION

The state of the Orbiter/payload system is advanced timewise in steps equal to the user-specified plot time interval t. The basic equations of motion, which are referenced to the rotating local vertical coordinate system illustrated in Figure 4, are described in Sections 4.2.1 through 4.2.3.

4.2.1 Rotational Motion

Since rotational accelerations are not modeled, and since each vehicle is permitted only one degree of rotational freedom, the pitch angles of the Shuttle Orbiter and the payload at the end of a time step t are described simply by

$$\alpha_s = \alpha_{so} + \dot{\alpha}_s t \tag{5}$$

and

$$\alpha = \alpha_o + \dot{\alpha} t \quad , \tag{6}$$

where the subscript o denotes the value of a variable at the beginning of the time step.

For the purpose of approximating the effects of atmospheric drag accelerations, the pitch angles are also calculated at the midpoint of the time step, thus:

$$\alpha_s' = \alpha_{so} + 1/2\, \dot{\alpha}_s t \tag{7}$$

and

$$\alpha' = \alpha_o + 1/2\ \dot{\alpha}\ t \quad . \tag{8}$$

4.2.2 Differential Drag Acceleration

The frontal area of the payload at mid-step time is given by

$$A = (\pi\ d^2/4)\ |\cos \alpha'| + \ell\ d|\sin \alpha'| \quad , \tag{9}$$

where ℓ and d are the length and diameter of the payload. The drag force acting on the payload is then given by

$$D = C_D\ q\ A \quad , \tag{10}$$

where C_D is supplied as input and q is the dynamic pressure defined by Equations (4a) through (4c). The dynamic pressure acting on the payload is assumed to be constant during any particular run and equal to that acting on the Shuttle.

The Shuttle drag coefficient is based on the theoretical wing planform area of 2690 ft^2, and is calculated by use of the equation

$$C_{Ds} = 0.72115 + 2.46205\ |\sin \alpha_s'|^{1.20124} \quad , \tag{11}$$

which was taken from Reference 7. The drag force acting on the Shuttle is then obtained from the equation

$$D_s = 2690\ q\ C_{Ds} \quad . \tag{12}$$

The differential drag acceleration (measured in ft/sec^2), which acts on the payload along the local vertical X axis and which is assumed to be constant during the time step t, is obtained from the equation

$$f_x = 32.174\ \left[(D_s/W_s) - (D/W) \right] \quad . \tag{13}$$

where W and W_s are the payload and Shuttle weights.

It should be noted that the drag equations used in this program do not account for aerodynamic shadowing effects. It is also reiterated that the same dynamic pressure q is assumed to act on both the payload and the Orbiter, and furthermore that it is assumed to remain constant during any given PMPP run. Dynamic pressure variations resulting from sources such as orbit decay, earth oblateness, orbit eccentricity and inclination, orientation of the orbit relative to the subsolar point, and variations in solar activity are not modeled.

4.2.3 Translational Motion

Translational motion of the payload CG relative to the Orbiter CG is calculated by integrating the Clohessy-Wiltshire (CW) differential equations

$$\ddot{X} - 2\omega\dot{Z} = f_x \quad , \tag{14}$$

$$\ddot{Y} + \omega^2 Y = f_y \quad , \tag{15}$$

and

$$\ddot{Z} + 2\omega\dot{X} - 3\omega^2 Z = f_z \quad , \tag{16}$$

where f_x, f_y, and f_z represent constant differential accelerations resulting from nongravitational forces acting parallel to the axes of the rotating coordinate system depicted in Figure 4. These equations, which are derived in Reference 8, represent approximations of the true differential equations of relative motion. They are valid when the orbit eccentricity and the intervehicular distance are both small.

Equations (14) through (16) can be integrated twice in closed form to obtain analytic expressions for the velocity and position of the payload relative to the Orbiter as functions of time. In Reference 8, the integrations were carried out only for the special case where $f_x = f_y = f_z = 0$. Since the subroutine (labeled . and detailed in steps 1750 through 1960 of Appendix C) used to calculate translational motion in this program allows

arbitrary values to be assigned to f_x, f_y, and f_z, the velocity and position equations will be derived here in their more general form even though f_y and f_z are always assigned values of zero in the PMPP.

Taking the simpler problem first, the equations for out-of-plane motion can be obtained by rewriting Equation (15) in the form

$$\ddot{Y} + \omega^2 \left(Y - f_y/\omega^2 \right) = 0 \quad . \tag{17}$$

This can be recognized easily as the equation of simple harmonic motion, having the solution

$$Y - f_y/\omega^2 = \left(Y_o - f_y/\omega^2 \right) \cos \omega t + \left(\dot{Y}_o/\omega \right) \sin \omega t \quad , \tag{18}$$

where, again, the subscript o denotes conditions at the beginning of the time step t. To obtain the analytic expression for out-of-plane velocity, Equation (18) is differentiated once with respect to t, thus yielding

$$\dot{Y} = - \omega \left(Y_o - f_y/\omega^2 \right) \sin \omega t + \dot{Y}_o \cos \omega t \quad . \tag{19}$$

Carrying out the multiplication in the first term on the right hand side of Equation (19), and multiplying both sides of Equation (18) by ω, the equations

$$(\omega Y - f_y/\omega) = (\omega Y_o - f_y/\omega) \cos \omega t + \dot{Y}_o \sin \omega t \tag{20}$$

and

$$\dot{Y} = - (\omega Y_o - f_y/\omega) \sin \omega t + \dot{Y}_o \cos \omega t \tag{21}$$

are obtained.

Since Equation (17) was recognized as the equation of simple harmonic motion, it is not surprising that Equations (20) and (21) have the form of the coordinate transformation equations

$$\underline{\overline{X}} = \underline{\overline{X}}_o \cos \Delta + \underline{\overline{Y}}_o \sin \Delta \tag{22}$$

and

$$\underline{\overline{Y}} = - \underline{\overline{X}}_o \sin \Delta + \underline{\overline{Y}}_o \cos \Delta \tag{23}$$

which are associated with the rotation of a Cartesian coordinate system through the angle Δ, as illustrated in Figure 5. The HP-9810A Math Block ROM (Reference 3) provides two functions which permit such a coordinate transformation to be calculated quite easily. They are the rectangular-to-polar and polar-to-rectangular functions which treat the contents of the bottom and middle display registers as the components of a two-dimensional vector. If $\underline{\overline{X}}_o$ is in the bottom register and $\underline{\overline{Y}}_o$ in the middle register, then activation of the A key causes $\underline{\overline{X}}_o$ and $\underline{\overline{Y}}_o$ to be replaced by the vector magnitude R and the angle θ_o, respectively (see Figure 5). To complete the transformation, one has only to replace θ_o with $\theta = \theta_o - \Delta$ in the middle register (leaving R in the bottom register) and then to activate the B key. This invokes the polar-to-rectangular function, which replaces R and θ with $\underline{\overline{X}}$ and $\underline{\overline{Y}}$ in the bottom and middle display registers.

If the quantity $(\omega Y_o - f_y/\omega)$ is substituted for $\underline{\overline{X}}_o$, $\dot{Y}_o$ for $\underline{\overline{Y}}_o$, ωt for Δ, $(\omega Y - f_y/\omega)$ for $\underline{\overline{X}}$, and $\dot{Y}$ for $\underline{\overline{Y}}$, the preceding paragraph describes how the out-of-plane position and velocity components are advanced through the time step t in the PMPP. As will be brought out later, a similar process is used to advance the in-plane position and velocity components. These computational shortcuts have been used to advantage with other electronic calculators (the HP-65 and the SR-52) that have built-in rectangular-to-polar and polar-to-rectangular coordinate transformation functions.

One note of explanation is needed with respect to the use of the rectangular-to-polar function on the HP-9810A. It may be seen in Appendix C

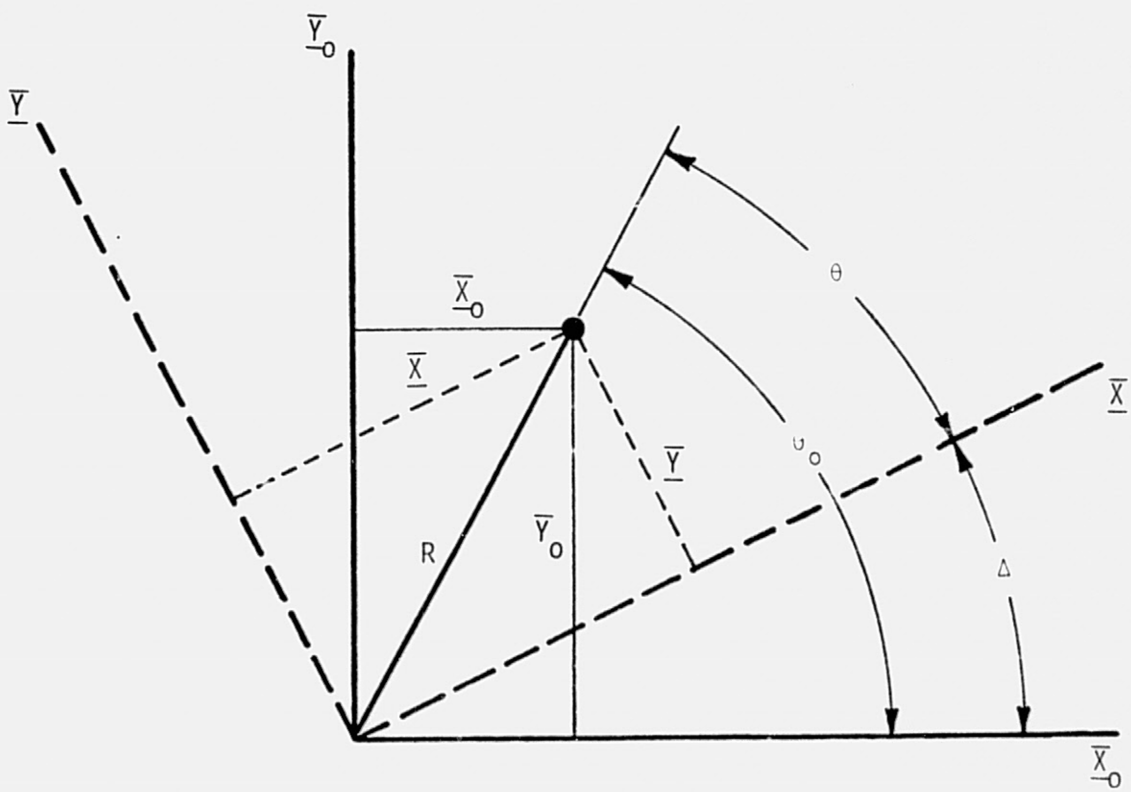

Figure 5. Rotation of Coordinates

that the A key is never activated in the main-line code. Instead, the rectangular-to-polar function is invoked by activating the F (user-definable function) key. This transfers execution control to a subroutine (steps 2003 through 2034) where some data manipulation and testing is done before and after activating the A key. This indirect method of invoking the rectangular-to-polar function is necessary because it was found in some cases at least that the contents of the top display register (which should remain unchanged) were destroyed by activation of the A key. In addition, if $\underline{X}_o = \underline{Y}_o = 0$ when A is activated, the HP-9810A Math Block ROM returns a value of 90° for the angle θ_o. Although acceptable in the case of the CW calculations under consideration here, this is undesirable in some coordinate transformation problems. Therefore, the F subroutine was coded so that a value of zero rather than 90° would be returned in such a circumstance.

Turning now to the problem of advancing the in-plane velocity and position components, the equation

$$\dot{X} = \dot{X}_o + 2\omega\,(Z - Z_o) + f_x\, t \tag{24}$$

results from integrating Equation (14) once with respect to t. This expression for $\dot{X}$ can then be substituted into Equation (16) to obtain

$$\ddot{Z} + \omega^2 \left\{ Z - \left[4Z_o - \left(2\dot{X}_o/\omega\right) + \left(f_z/\omega^2\right) - \left(2f_x/\omega^2\right)\omega t \right] \right\} = 0 \quad , \tag{25}$$

which has the solution

$$\begin{aligned} Z - \left[4Z_o - \left(2\dot{X}_o/\omega\right) + \left(f_z/\omega^2\right) - \left(2f_x/\omega^2\right)\omega t \right] \\ = \left\{ Z_o - \left[4Z_o - \left(2\dot{X}_o/\omega\right) + \left(f_z/\omega^2\right)\right] \right\} \cos \omega t \\ + \left\{ \left[\dot{Z}_o + \left(2f_x/\omega\right)\right] / \omega \right\} \sin \omega t \quad . \end{aligned} \tag{26}$$

The analytic expression for the vertical component of velocity is obtained by differentiating Equation (26) once with respect to t, thus:

$$\dot{Z} + 2f_x/\omega = -\omega \left\{ Z_o - \left[4Z_o - \left(2\dot{X}_o/\omega \right) + \left(f_z/\omega^2 \right) \right] \right\} \sin \omega t$$

$$+ \left[\dot{Z}_o + \left(2f_x/\omega \right) \right] \cos \omega t \quad . \tag{27}$$

Equations (26) and (27) can be rearranged to form the expressions

$$\omega\ (Z - Z_o) + [2\dot{X}_o - 3\omega Z_o - (f_z/\omega)] + (2f_x/\omega)\ \omega t$$

$$= [2\dot{X}_o - 3\omega Z_o - (f_z/\omega)] \cos \omega t + [\dot{Z}_o + (2f_x/\omega)] \sin \omega t \tag{28}$$

and

$$\dot{Z} + (2f_x/\omega) = -\ [2\dot{X}_o - 3\omega Z_o - (f_z/\omega)] \sin \omega t$$

$$+ [\dot{Z}_o + (2f_x/\omega)] \cos \omega t \quad . \tag{29}$$

Comparison of Equations (28) and (29) with Equations (22) and (23) reveals that, again, the previously described procedure for rotating coordinates by use of the rectangular-to-polar and the polar-to-rectangular functions can be used to simplify the calculation of Z and $\dot{Z}$. This time, the expression $[2\dot{X}_o - 3\omega Z_o - (f_z/\omega)]$ is substituted for $\underline{X}_o$, $[\dot{Z}_o + (2f_x/\omega)]$ for $\underline{Y}_o$, ωt for Δ, $[\omega\ (Z - Z_o) + \underline{X}_o + (2f_x/\omega)\ \omega t]$ for $\underline{X}$, and $[\dot{Z} + (2f_x/\omega)]$ for $\underline{Y}$.

Once the value of the quantity $\omega\ (Z - Z_o)$ is obtained from the solution of Equation (28), the downtrack velocity component $\dot{X}$ can be computed easily by use of Equation (24). It now remains only to drive an analytic expression from the downtrack position component X. This can be done by combining Equations (24) and (28) to obtain the expression

$$\dot{X} = \dot{X}_o + 2\,(\underline{\overline{X}}_o \cos \omega t + \underline{\overline{Y}}_o \sin \omega t) - 2\underline{\overline{X}}_o - 3f_x t \quad , \tag{30}$$

where (as in the preceding paragraph)

$$\underline{\overline{X}}_o = 2\dot{X}_o - 3\omega Z_o - f_z/\omega \tag{31}$$

and

$$\underline{\overline{Y}}_o = \dot{Z}_o + (2f_x/\omega) \quad . \tag{32}$$

Integration of Equation (30) once with respect to t then yields

$$X - X_o = \dot{X}_o\, t + \frac{2}{\omega}\left[\underline{\overline{X}}_o \sin \omega t - \underline{\overline{Y}}_o \cos \omega t + \underline{\overline{Y}}_o\right]$$

$$- 2\,\underline{\overline{X}}_o\, t - 3/2\, f_x t^2 \quad . \tag{33}$$

Equation (33), when combined with Equation (29) and rearranged, yields finally

$$\omega\,(X - X_o) = \dot{X}_o\, \omega t - 2\,[(\dot{Z} - \dot{Z}_o) + \underline{\overline{X}}_o\, \omega t] - 3/2\, f_x \omega t^2 \quad , \tag{34}$$

which simplifies the computation by permitting the previously-computed value of $\dot{Z}$ to be used in the calculation of X.

4.3 TRANSFORMATION FROM PAYLOAD BODY TO ORBITER BODY COORDINATES

Because its centerline is restricted in PMPP such that it always lies parallel to the Orbiter's plane of symmetry, the profile of the cylindrical payload always appears as a rectangle in the HP-9862A plots. The four corners of this rectangle have the coordinates $X_{PB} = \pm\, \ell/2$ and $Z_{PB} = \pm\, d/2$ relative to the payload body axes, which originate at the payload CG. The corner coordinates are transformed from payload body to Orbiter body coordinates in the subroutine labeled π which is detailed in steps 1136 through 1181 of Appendix C.

The geometry associated with the total coordinate transformation process is shown in Figure 6. Using the procedure described in Section 4.2.3, the

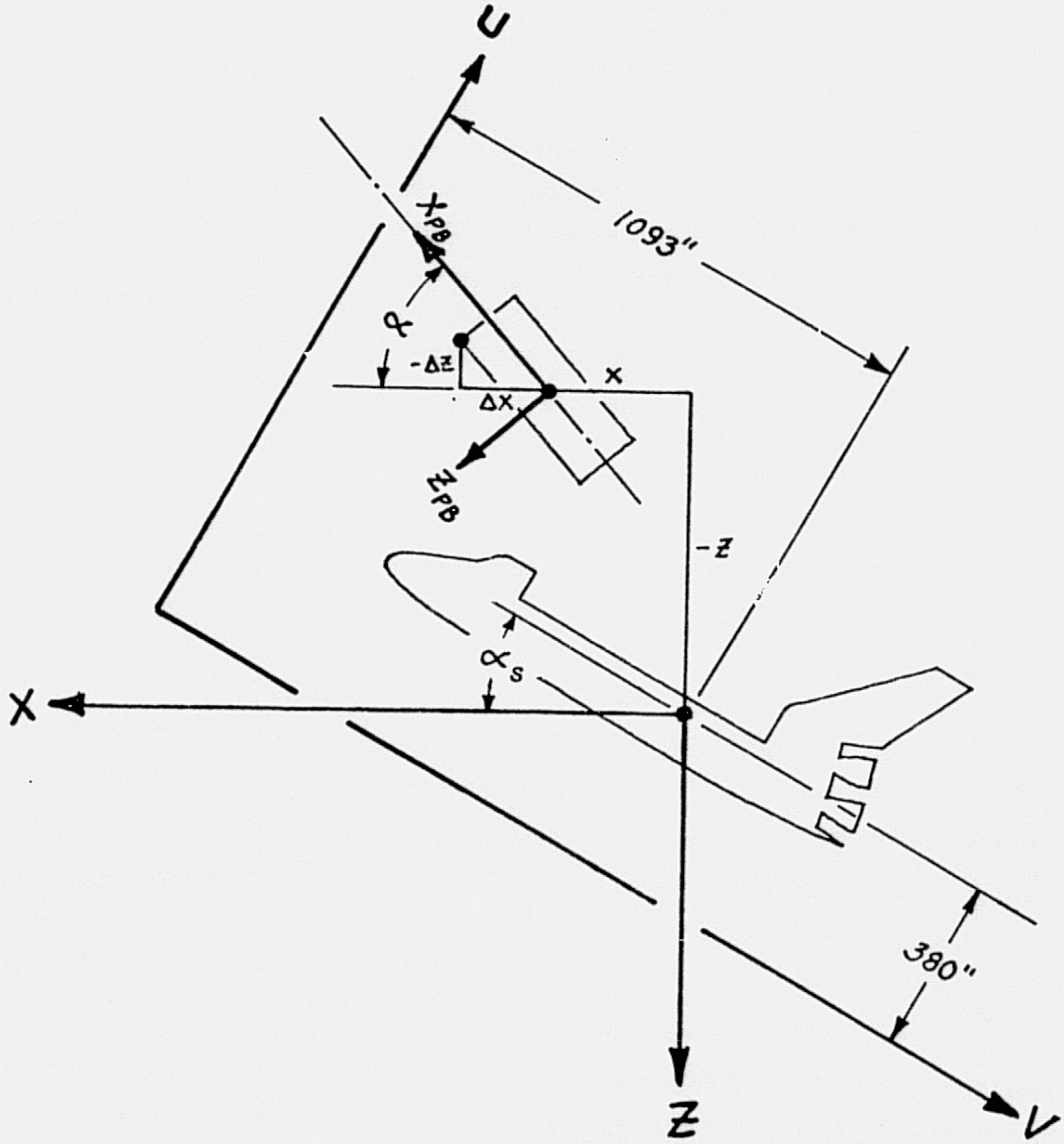

Figure 6. Transformation from Payload Body to Orbiter Body Coordinates

coordinates (X_{PB}, Z_{PB}) are first rotated through the angle α to obtain their counterparts (ΔX, ΔZ) in a system whose axes are parallel to those of the local vertical system. The origin is then translated to the Orbiter CG by adding ΔX and ΔZ to X and Z (the coordinates of the payload CG relative to the Orbiter CG). This yields the local vertical coordinates of the corner in question, which are then rotated through the angle α_s to obtain their counterparts in a system whose axes are parallel to the Orbiter body axes. These coordinates are multiplied by 12 to change their units from feet to inches, and then subtracted from the coordinates of the Orbiter CG (U = 1093, V = 380) to complete the transformation to the Orbiter body system, as required for input to the Math Block plotter scaling function.

REFERENCES

1. Hewlett-Packard Co., "Hewlett-Packard 9810A Calculator, Operating and Programming," 1971.

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3. Hewlett-Packard Co., "Hewlett-Packard 9810A Calculator Mathematics Block, Operating Manual," 1971.

4. Larry D. Davis, "Coordinate Systems for the Space Shuttle Program," NASA TM X-58153, Lyndon B. Johnson Space Center, October 1974.

5. Lyndon B. Johnson Space Center, "Shuttle Operational Data Book, Volume I, Shuttle Systems Performance and Constraints Data," Document No. JSC-08934 (Vol. I), Revised 18 May 1976.

6. Lyndon B. Johnson Space Center, "Space Shuttle System Payload Accommodations, Level II Program Definition and Requirements, Volume XIV," Document No. JSC-07700, Vol. XIV, Revision D, Revised 27 April April 1976.

7. M. D. Zuteck, "Shuttle On-Orbit Aerodynamic Model," TRW IOC No. 76:2511.4-04, 16 January 1976.

8. R. S. Dunning, The Orbital Mechanics of Flight Mechanics, NASA SP-325, Langley Research Center, 1973.

APPENDIX A:

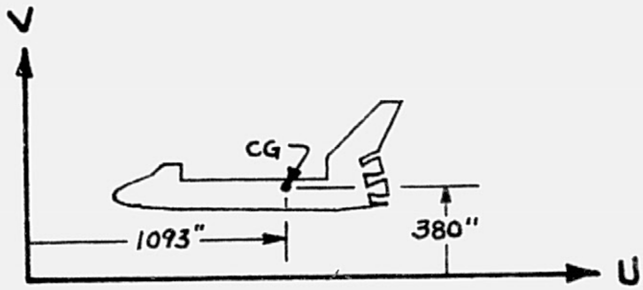
OSEPP/PMPP OPERATING INSTRUCTIONS

OPERATING INSTRUCTIONS

ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)
AND
PAYLOAD MOTION PLOT PROGRAM (PMPP)

1. Turn on HP-9810A calculator and HP-9862A plotter power switches.

2. Store logical plotting boundary coordinates in HP-9810A data registers 001 thru 004. Logical coordinates are expressed in inches and are measured in the Orbiter Structural Body Coordinate System (Figure 23, NASA TM X-58153).



REGISTER	BOUNDARY	VALUE*
001	U_{min}	-200
002	U_{max}	1900
003	V_{min}	200
004	V_{max}	1650

*For standard 8-1/2" x 11" plotting form with P = 8.75" and Q = 6.04" (other values can be used, see section 2.3 of program document).

3. Position sheet of paper on HP-9862A plotting board and turn on electrostatic paper hold. Then,

   a. Adjust plotting pen location at lower left corner of plotting area (U_{min}, V_{min}).

   b. Adjust plotting pen location at upper right corner of plotting area (U_{max}, V_{max}).

4. Press END and then LOAD on HP-9810A keyboard and load ORBITER SIDE ELEVATION PLOT PROGRAM from magnetic cards (4 sides)

   a. Press END and then CONTINUE. Calculator will plot side elevation view of Orbiter, including CG location.

   b. To plot RMS reach envelope, press GO TO, LABEL, E, CONTINUE

   c. To plot RMS operator's fields of view, press GO TO, LABEL, L, CONTINUE.

   d. To plot field of view thru CDAS, press GO TO, LABEL, N, CONTINUE.

5. Press END and then LOAD on HP-9810A keyboard and load PAYLOAD MOTION PLOT PROGRAM from magnetic cards (4 sides)

   a. Press END and then CONTINUE. Calculator will print prompting message for each of the required program inputs. (See next page.)

   b. When calculator stops after a prompting message, enter desired value(s) into display register(s) and then press CONTINUE.

   c. After final program input (DT) is loaded, press CONTINUE to initiate automatic plotting of payload positions at the specified time intervals.

6. To plot another payload trajectory on same display, go back to step 5 a.

7. To create new display, turn off paper hold on HP-9862A, remove completed display, and go back to step 3.

INPUT DATA

PAYLOAD MOTION PLOT PROGRAM

PROMPTING MESSAGE	RESPONSE [1]
ALT (NM) =	Load orbit altitude (nautical miles) into bottom display register.
ORB WT (LB) =	Load Orbiter weight into bottom display register.
ORB PITCH (DEG) =	Load Orbiter pitch angle [2] into bottom display register.
ORB PITCH RATE (DEG/SEC) =	Load Orbiter pitch rate [3] into bottom display register.
PL LENGTH (FT) =	Load payload length into bottom display register.
PL DIA (FT) =	Load payload diameter into bottom display register.
PL CD =	Load payload drag coefficient into bottom display register.
PL WT (LB) =	Load payload weight into bottom display register.
PL PITCH (DEG) =	Load payload pitch angle [2] into bottom display register.
PL PITCH RATE (DEG/SEC) =	Load payload pitch rate [3] into bottom display register.
TIME (H, M, S) =	Load initial time into display registers HOURS → TOP REGISTER MINUTES → MIDDLE REGISTER SECONDS → BOTTOM REGISTER.

PROMPTING MESSAGE	RESPONSE △1
PL POS (FT) =	Load initial payload position △4 into display registers X → TOP REGISTER Y → MIDDLE REGISTER Z → BOTTOM REGISTER.
PL VEL (FPS) =	Load initial payload velocity △4 into display registers $\dot{X}$ → TOP REGISTER $\dot{Y}$ → MIDDLE REGISTER $\dot{Z}$ → BOTTOM REGISTER.
TSTOP (H, M, S) =	Load stop time into display registers HOURS → TOP REGISTER MINUTES → MIDDLE REGISTER SECONDS → BOTTOM REGISTER.
DT (H, M, S) =	Load time interval for plotting payload positions HOURS → TOP REGISTER MINUTES → MIDDLE REGISTER SECONDS → BOTTOM REGISTER.

NOTES:

△1 Program always transfers current stored values into display register(s) before prompting. If old value satisfactory, press CONTINUE . Otherwise, load new value(s) and then press CONTINUE .

△2 Pitch angles are measured from the instantaneous local horizontal plane. Yaw and roll angles are assumed to be zero.

△3 To hold constant inertial attitude, recall ω (radians/sec) from data register 020 and multiply by 57.2957795.

4 Payload position and velocity are measured relative to the orbiter CG in a (rotating) local-vertical coordinate system. Axes are directed as follows:

- Z TOWARD CENTER OF EARTH
- Y OPPOSITE TO THE ORBIT'S ANGULAR MOMENTUM VECTOR
- X COMPLETE RH COORDINATE SYSTEM (DOWNTRACK).

5 Payload CG is assumed to be at centroid of cylinder. Pitch angle measured from local horizontal plane to cylinder centerline.

6 Payload drag coefficient based on projected frontal area, which is calculated by program as a function of pitch angle.

APPENDIX B:

OSEPP CODE

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (USCPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0000	K				
1	I				
2	CNT				
3	CNT				
4	CNT				
5	CNT				
6	CNT				
7	CNT				
8	CNT				
9	2				
0	9				
1	1				
2	↑				
3	1				
4	6				
5	1				
6	3		1613	291	
7	K				
8	FMT				
9	↑				
0	FMT				
1	↑				
2	2				
3	9				
4	8				
5	↑				
6	1				
7	5				
8	3				
9	4		1534	298	
0	K				
1	FMT				
2	↓				
3	3				
4	3				
5	6				
6	↑				
7	1				
8	5				
9	2				
0	6		1526	336	
1	K				
2	FMT				
3	↓				
4	3				
5	3				
6	5				
7	↑				
8	1				
9	5				

STEP	KEY	CODE	X	Y	Z
0050	5				
1	0		1550	335	
2	K				
3	FMT				
4	↓				
5	3				
6	3				
7	4				
8	↑				
9	1				
0	5				
1	7				
2	5		1575	334	
3	K				
4	FMT				
5	↓				
6	3				
7	3				
8	4				
9	↑				
0	1				
1	6				
2	0				
3	0		1600	334	
4	K				
5	FMT				
6	↓				
7	3				
8	3				
9	6				
0	↑				
1	1				
2	6				
3	2				
4	3		1623	336	
5	K				
6	FMT				
7	↓				
8	4				
9	1				
0	2				
1	↑				
2	1				
3	6				
4	0				
5	9		1609	412	
6	K				
7	FMT				
8	↓				
9	4				

STORAGE

b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

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PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (USE FF)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
0200	3				
1	↑				
2	1				
3	5				
4	9				
5	8		1598	453	
6	K				
7	FMT				
8	↓				
9	5				
0	2				
1	6				
2	↑				
3	1				
4	5				
5	7				
6	8		1578	526	
7	K				
8	FMT				
9	↓				
0	5				
1	1				
2	7				
3	↑				
4	1				
5	5				
6	5				
7	0		1550	517	
8	K				
9	FMT				
0	↓				
1	5				
2	0				
3	6				
4	↑				
5	1				
6	5				
7	2				
8	5		1525	506	
9	K				
0	FMT				
1	↓				
2	4				
3	8				
4	9				
5	↑				
6	1				
7	5				
8	0				
9	0		1500	489	

STEP	KEY	CODE	x	y	z
0250	K				
1	FMT				
2	↓				
3	4				
4	8				
5	3				
6	↑				
7	1				
8	4				
9	9				
0	2		1492	483	
1	K				
2	FMT				
3	↓				
4	5				
5	1				
6	9				
7	↑				
8	1				
9	4				
0	8				
1	2		1482	519	
2	K				
3	FMT				
4	↓				
5	5				
6	6				
7	2				
8	↑				
9	1				
0	5				
1	7				
2	6		1576	562	
3	K				
4	FMT				
5	↓				
6	8				
7	1				
8	6				
9	↑				
0	↑				
1	1				
2	7				
3	0				
4	0		1700	816	816
5	K				
6	FMT				
7	↓				816
8	↓			816	
9	1				

STORAGE	
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 4 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0300	5				
1	9				
2	3		1593	816	
3	K				
4	FMT				
5	↓				
6	5				
7	4				
8	8				
9	↑				
0	1				
1	3				
2	2				
3	5		1325	548	
4	K				
5	FMT				
6	↓				
7	5				
8	4				
9	0				
0	↑				
1	1				
2	3				
3	1				
4	7		1317	540	
5	K				
6	FMT				
7	↓				
8	5				
9	3				
0	3				
1	↑				
2	1				
3	3				
4	1				
5	1		1311	533	
6	K				
7	FMT				
8	↓				
9	5				
0	2				
1	4				
2	↑				
3	1				
4	3				
5	0				
6	8		1308	524	
7	K				
8	FMT				
9	↓				

STEP	KEY	CODE	X	Y	Z
0350	5				
1	1				
2	6				
3	↑				
4	1				
5	3				
6	0				
7	7		1307	516	
8	↑		1307	1307	516
9	ROLL↑		516	1307	1307
0	X⇌Y		1307	516	1307
1	K				
2	FMT				
3	↓				
4	↓			1307	1307
5	4				
6	2				
7	0		420	1307	1307
8	↑		420	420	1307
9	ROLL↑		1307	420	420
0	K				
1	FMT				
2	↓				420
3	↓			420	420
4	5				
5	7				
6	6		576	420	420
7	↑		576	576	420
8	ROLL↑		420	576	576
9	X⇌Y		576	420	576
0	K				
1	FMT				
2	↓				576
3	↓			576	576
4	5				
5	0				
6	0		500	576	576
7	↑		500	500	576
8	ROLL↑		576	500	500
9	K				
0	FMT				
1	↓				500
2	↓			500	500
3	↓		500	500	500
4	K				
5	FMT				
6	↓				
7	4				
8	9				
9	9				

STORAGE	
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
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4	
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0	
1	
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ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
0400	↑				
1	4				
2	9				
3	1		491	499	
4	K				
5	FMT				
6	↓				
7	4				
8	9				
9	3				
0	↑				
1	4				
2	8				
3	0		480	493	
4	K				
5	FMT				
6	↓				
7	4				
8	8				
9	9				
0	↑				
1	4				
2	7				
3	2		472	489	
4	K				
5	FMT				
6	↓				
7	4				
8	5				
9	0				
0	↑				
1	4				
2	3				
3	4		434	450	
4	K				
5	FMT				
6	↓				
7	3				
8	9				
9	4				
0	↑				
1	3				
2	0				
3	0		300	394	
4	K				
5	FMT				
6	↓				
7	3				
8	8				
9	5				

STEP	KEY	CODE	x	y	z
0450	↑				
1	2				
2	8				
3	3		293	385	
4	K				
5	FMT				
6	↓				
7	3				
8	7				
9	8				
0	↑				
1	2				
2	7				
3	0		270	378	
4	K				
5	FMT				
6	↓				
7	3				
8	7				
9	2				
0	↑				
1	2				
2	5				
3	9		259	372	
4	K				
5	FMT				
6	↓				
7	3				
8	6				
9	4				
0	↑				
1	2				
2	5				
3	0		250	364	
4	K				
5	FMT				
6	↓				
7	SET FLG				
8	2				
9	6				
0	2				
1	.				
2	5		262.5		
3	X→( )				
4	0				
5	5				
6	1				
7	3				
8	3				
9	8		338		

STORAGE

Register	Contents
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

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PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSE PP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z
0500	X→( )					0550	2				
1	0					1	8				
2	5					2	6		286	300	
3	2					3	K				
4	2					4	FMT				
5	7					5	↓				
6	.					6	2				
7	5		27.5			7	9				
8	X→( )					8	4				
9	0					9	↑				
0	5					0	3				
1	3					1	1				
2	1					2	2		312	294	
3	3					3	K				
4	5		135			4	FMT				
5	X→( )					5	↓				
6	0					6	2				
7	5					7	8				
8	4					8	9				
9	2					9	↑				
0	3					0	3				
1	7		237			1	3				
2	X→( )					2	7		337	289	
3	0					3	K				
4	5					4	FMT				
5	5					5	↓				
6	1					6	2				
7	0		10			7	8				
8	X→( )					8	6				
9	0					9	↑				
0	5					0	3				
1	6					1	6				
2	GOTO					2	2		362	286	
3	SUB					3	K				
4	LBL					4	FMT				
5	C					5	↓				
6	3					6	2				
7	0					7	8				
8	8					8	3				
9	↑					9	↑				
0	2					0	3				
1	6					1	8				
2	3		263	308		2	7		387	283	
3	K					3	K				
4	FMT					4	FMT				
5	↓					5	↓				
6	3					6	2				
7	0					7	8				
8	0					8	0				
9	↑					9	↑				

STORAGE

Register	Contents
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 7 OF 18

ROM'S 1 MATH BLOCK 2 ____ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ____
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ____

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
0600	4				
1	1				
2	4		414	280	
3	K				
4	FMT				
5	↓				
6	2				
7	7				
8	8				
9	↑				
0	4				
1	5				
2	0		450	278	
3	K				
4	FMT				
5	↓				
6	2				
7	7				
8	5				
9	↑				
0	4				
1	9				
2	2		492	275	
3	K				
4	FMT				
5	↓				
6	2				
7	7				
8	3				
9	↑				
0	5				
1	3				
2	5		535	273	
3	K				
4	FMT				
5	↓				
6	2				
7	7				
8	2				
9	↑				
0	5				
1	7				
2	5		575	272	
3	K				
4	FMT				
5	↓				
6	2				
7	7				
8	1				
9	↑				

STEP	KEY	CODE	x	y	z
0650	6				
1	2				
2	5		625	271	
3	K				
4	FMT				
5	↓				
6	2				
7	6				
8	9				
9	↑				
0	6				
1	7				
2	5		675	269	
3	K				
4	FMT				
5	↓				
6	2				
7	6				
8	8				
9	↑				
0	7				
1	2				
2	5		725	268	
3	K				
4	FMT				
5	↓				
6	2				
7	6				
8	7				
9	↑				
0	7				
1	7				
2	5		775	267	
3	K				
4	FMT				
5	↓				
6	2				
7	6				
8	5				
9	↑				
0	9				
1	0				
2	0		900	265	
3	K				
4	FMT				
5	↓				
6	2				
7	6				
8	4				
9	↑				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0700	1				
1	0				
2	0				
3	0		1000	264	
4	K				
5	FMT				
6	↓				
7	2				
8	6				
9	3				
0	↑				
1	1				
2	1				
3	0				
4	0		1100	263	
5	K				
6	FMT				
7	↓				
8	2				
9	6				
0	2				
1	↑				
2	1				
3	1				
4	5				
5	0		1150	262	
6	K				
7	FMT				
8	↓				
9	2				
0	6				
1	1				
2	↑				
3	1				
4	2				
5	5				
6	0		1250	261	
7	K				
8	FMT				
9	↓				
0	2				
1	6				
2	1				
3	↑				
4	1				
5	3				
6	0				
7	0		1300	261	
8	K				
9	FMT				

STEP	KEY	CODE	X	Y	Z
0750	↓				
1	2				
2	6				
3	4				
4	↑				
5	1				
6	3				
7	5				
8	0		1350	264	
9	K				
0	FMT				
1	↓				
2	2				
3	6				
4	7				
5	↑				
6	1				
7	4				
8	0				
9	0		1400	267	
0	K				
1	FMT				
2	↓				
3	2				
4	7				
5	1				
6	↑				
7	1				
8	4				
9	5				
0	0		1450	271	
1	K				
2	FMT				
3	↓				
4	2				
5	7				
6	5				
7	↑				
8	1				
9	5				
0	0				
1	0		1500	275	
2	K				
3	FMT				
4	↓				
5	2				
6	8				
7	1				
8	↑				
9	1				

STORAGE

Register	Contents
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 9 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z	STORAGE	
0800	5					0850	0		0			b	
1	5					1	X→( )					a	
2	0		1550	281		2	0					0	
3	K					3	5					1	Umin
4	FMT					4	4					2	Umax
5	↓					5	3					3	Vmin
6	2					6	6					4	Vmax
7	8					7	0		360			5	
8	8					8	X→( )					6	
9	↑					9	0					7	
0	1					0	5					8	
1	6					1	5					9	
2	0					2	2					0	
3	0		1600	288		3	4					51	h
4	K					4	X→( )					52	k
5	FMT					5	0					53	r
6	↓					6	5					54	θ_1
7	2					7	6					55	θ_2
8	9					8	GOTO					56	N
9	0					9	SUB					57	θ
0	↑					0	LBL					58	$\delta\theta$
1	1					1	C					59	K
2	6					2	3					0	
3	1					3	8					61	u
4	3		1613	290		4	0					62	v
5	K					5	↑					63	ϕ
6	FMT					6	1					64	L
7	↓					7	0					65	Δ
8	CLEAR		0	0	0	8	7					66	ℓ
9	1					9	7		1077	380		7	
0	0					0	K					8	
1	9					1	FMT					9	
2	3		1093			2	↓					0	
3	X→( )					3	3					1	
4	0					4	9					2	
5	5					5	6					3	
6	1					6	↑					4	
7	3					7	1					5	
8	8					8	0					6	
9	0		380			9	9					7	
0	X→( )					0	3		1093	396		8	
1	0					1	↑		1093	1093	396	9	
2	5					2	ROLL↑		396	1093	1093	0	
3	2					3	X⇄Y		1093	396	1093	1	
4	1					4	K					2	
5	6		16			5	FMT					3	
6	X→( )					6	↑				1093	4	
7	0					7	↓			1093		5	
8	5					8	3					6	
9	3					9	6					7	

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ____ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z
0900	4		364	1093		0950	5		144.5		
1	X⇄Y		1093	364		1	X→( )				
2	K					2	0				
3	FMT					3	5				
4	↓					4	5				
5	STOP					5	1				
6	CNT					6	0				
7	CNT					7	0		100		
8	CNT					8	X→( )				
9	CNT					9	0				
0	CNT					0	5				
1	CNT					1	6				
2	CNT					2	GOTO				
0913	LBL					3	SUB				
4	E					4	LBL				
5	CLEAR		0	0	0	5	C				
6	6					6	CLEAR		0	0	0
7	7					7	4				
8	9					8	6				
9	.					9	4				
0	5		679.5			0	.				
1	X→( )					1	2		464.2		
2	0					2	X→( )				
3	5					3	0				
4	1					4	5				
5	4					5	1				
6	4					6	5				
7	4					7	9				
8	.					8	8				
9	8		444.8			9	.				
0	X→( )					0	4		598.4		
1	0					1	X→( )				
2	5					2	0				
3	2					3	5				
4	6					4	2				
5	0					5	3				
6	0		600			6	3				
7	X→( )					7	5				
8	0					8	.				
9	5					9	5		335.5		
0	3					0	X→( )				
1	0		0			1	0				
2	X→( )					2	5				
3	0					3	3				
4	5					4	1				
5	4					5	4				
6	1					6	4				
7	4					7	.				
8	4					8	5		144.5		
9	.					9	X→( )				

STORAGE

Register	Contents
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 11 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z
1000	0					1050	1				
1	5					1	2				
2	4					2	5				
3	2					3	X→( )				
4	2					4	0				
5	6					5	6				
6	.					6	3				
7	5		226.5			7	1				
8	X→( )					8	8				
9	0					9	0				
0	5					0	0		1800		
1	5					1	X→( )				
2	4					2	0				
3	1		41			3	6				
4	X→( )					4	4				
5	0					5	5				
6	5					6	0		50		
7	6					7	X→( )				
8	GOTO					8	0				
9	SUB					9	6				
0	LBL					0	5				
1	C					1	GOTO				
2	$\boxed{\text{STOP}}$					2	SUB				
3	CNT					3	LBL				
4	CNT					4	D				
5	CNT					5	4				
6	CNT					6	5		45		
7	CNT					7	X→( )				
8	CNT					8	0				
9	CNT					9	6				
0	CNT					0	3				
1031	LBL					1	GOTO				
2	L					2	SUB				
3	5					3	LBL				
4	5					4	D				
5	1					5	5				
6	.					6	6				
7	7					7	6				
8	5		551.75			8	.				
9	X→( )					9	7		566.7		
0	0					0	X→( )				
1	6					1	0				
2	1					2	6				
3	4					3	1				
4	8					4	4				
5	7		487			5	8				
6	X→( )					6	3				
7	0					7	.				
8	6					8	6		483.6		
9	2					9	X→( )				

STORAGE

Register	Contents
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ____ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ____
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ____

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z	STORAGE	
1100	0					1150	6					b	
1	6					1	2					a	
2	2					2	9					0	
3	3					3	5		95			1	Umin
4	0		30			4	X→( )					2	Umax
5	X→( )					5	0					3	Vmin
6	0					6	6					4	Vmax
7	6					7	3					5	
8	3					8	CNT					6	
9	GOTO					9	2					7	
0	SUB					0	4					8	
1	LBL					1	0					9	
2	D					2	0		2400			0	
3	3					3	X→( )					51	h
4	2					4	0					52	k
5	CHS		-32			5	6					53	r
6	X→( )					6	4					54	θ_1
7	0					7	2					55	θ_2
8	6					8	5		25			56	N
9	3					9	X→( )					57	θ
0	GOTO					0	0					58	$\delta\theta$
1	SUB					1	6					59	K
2	LBL					2	5					0	
3	D					3	GOTO					61	u
4	$\boxed{\text{STOP}}$					4	SUB					62	v
5	CNT					5	LBL					63	ϕ
6	CNT					6	D					64	L
7	CNT					7	8					65	Δ
8	CNT					8	5		85			66	ℓ
9	CNT					9	X→( )					7	
0	CNT					0	0					8	
1	CNT					1	6					9	
2	CNT					2	3					0	
1133	LBL					3	GOTO					1	
4	N					4	SUB					2	
5	5					5	LBL					3	
6	5					6	D					4	
7	1					7	$\boxed{\text{STOP}}$					5	
8	.					8						6	
9	7					9						7	
0	5		551.75			0						8	
1	X→( )					1						9	
2	0					2						0	
3	6					3						1	
4	1					4						2	
5	4					5						3	
6	8					6						4	
7	7		487			7						5	
8	X→( )					8						6	
9	0					9						7	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z
1200						1250					
1						1					

STORAGE

Register	Contents
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
51	h
52	$\dot{h}$
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 14 OF 18

ROM'S 1 MATH BLOCK 2 ________ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ________
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ________

TOTAL PROGRAM STEPS [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z	STORAGE	
1300						1350						b	
1						1						a	
2						2						0	
3						3						1	Umin
4						4						2	Umax
5						5						3	Vmin
6						6						4	Vmax
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						51	h
4						4						52	k
5						5						53	r
6						6						54	θ_1
7						7						55	θ_2
8						8						56	N
9						9						57	θ
0						0						58	$\delta\theta$
1						1						59	K
2						2						0	
3						3						61	u
4						4						62	v
5						5						63	ϕ
6						6						64	L
7						7						65	Δ
8						8						66	ℓ
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						1	
4						4						2	
5						5						3	
6						6						4	
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						1	
4						4						2	
5						5						3	
6						6						4	
7						7						5	
8						8						6	
9						9						7	

ALPHA

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 15 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z	STORAGE	
1400						1450						b	
1						1						a	
2						2						0	
3						3						1	Umin
4						4						2	Umax
5						5						3	Vmin
6						6						4	Vmax
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						51	h
4						4						52	k
5						5						53	r
6						6						54	θ_1
7						7						55	θ_2
8						8						56	N
9						9						57	θ
0						0						58	$\delta\theta$
1						1						59	K
2						2						0	
3						3						61	u
4						4						62	v
5						5						63	ϕ
6						6						64	L
7						7						65	Δ
8						8						66	ℓ
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						1	
4						4						2	
5						5						3	
6						6						4	
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						0	
3						3						1	
4						4						2	
5						5						3	
6						6						4	
7						7						5	
8						8						6	
9						9						7	

ALPHA

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PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
1500	LBL				
1	C				
2	X←( )				
3	0				
4	5				
5	5		θ_2		
6	↑		θ_2	θ_2	
7	X←( )				
8	0				
9	5				
0	4		θ_1	θ_2	
1	X→( )				
2	0				
3	5				
4	7				
5	−		θ_1	$\Delta\theta$	
6	X←( )				
7	0				
8	5				
9	6		N	$\Delta\theta$	
0	÷		N	$\delta\theta$	
1	Y→( )				
2	0				
3	5				
4	8				
5	0		0	$\delta\theta$	
6	X→( )				
7	0				
8	5				
9	9				
1530	X←( )				
1	0				
2	5				
3	7		θ		
4	↑		θ	θ	
5	X←( )				
6	0				
7	5				
8	3		r	θ	
9	B		ΔU	ΔV	
0	X←( )				
1	+				
2	0				
3	5				
4	1		U	ΔV	
5	Y⇄( )				
6	+				
7	0				
8	5				
9	2		U	V	

STEP	KEY	CODE	x	y	z
0	IF FLG				
1	1				
NO 2	5				
3	6				
4	3				
5	K				
6	FMT				
7	↑				
8	GOTO				
9	1				
0	5				
1	6				
2	6				
1563	K				
4	FMT				
5	↓				
1566	X←( )				
7	0				
8	5				
9	9		K		
0	↑		K	K	
1	X←( )				
2	0				
3	5				
4	6		N	K	
5	X>Y				
6	1				
NO 7	5				
8	8				
9	5				
0	GOTO				
1	1				
2	6				
3	0				
4	6				
1585	1		1	K	
6	+		1	K+1	
7	Y→( )				
8	0				
9	5				
0	9				
1	X←( )				
2	0				
3	5				
4	8		$\delta\theta$		
5	X→( )				
6	+				
7	0				
8	5				
9	7				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
0	
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

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PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 17 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
1600	SET FLG				
1	GOTO				
2	1				
3	5				
4	3				
5	0				
1606	RETURN				

STEP	KEY	CODE	X	Y	Z
1650					

STORAGE	
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	$\delta\theta$
59	K
61	u
62	v
63	ϕ
64	L
65	Δ
66	ℓ

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME ORBITER SIDE ELEVATION PLOT PROGRAM (OSEPP) PAGE 18 OF 18

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
1700	LBL				
1	D				
2	CLEAR		0	0	0
3	X→()				
4	0				
5	6				
6	6				
1707	X←()				
8	0				
9	6				
0	3		Ø		
1	↑		Ø	Ø	
2	X←()				
3	0				
4	6				
5	6		ℓ	Ø	
6	B		ΔU	ΔV	
7	X←()				
8	+				
9	0				
0	6				
1	1		U	ΔV	
2	Y⇄()				
3	+				
4	0				
5	6				
6	2		U	V	
7	IF FLG				
8	1				
NO 9	7				
0	5				
1	4				
2	K				
3	FMT				
4	↑				
5	.				
6	7				
7	5		.75		
8	X←()				
9	X				
0	0				
1	6				
2	5		.75 Δ		
3	X→()				
4	+				
5	0				
6	6				
7	6				
8	SET FLG				
9	GO TO				

STEP	KEY	CODE	x	y	z
1750	1				
1	7				
2	7				
3	0				
1754	K				
5	FMT				
6	↓				
7	.				
8	2				
9	5		.25		
0	X←()				
1	X				
2	0				
3	6				
4	5		.25 Δ		
5	X→()				
6	+				
7	0				
8	6				
9	6				
1770	X←()				
1	0				
2	6				
3	4		L		
4	↑		L	L	
5	X←()				
6	0				
7	6				
8	6		ℓ	L	
9	X<Y				
0	1				
1	7				
NO 2	0				
3	7				
4	RETURN				
5	END				
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					

STORAGE	
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
5	
6	
7	
8	
9	
0	
51	h
52	k
53	r
54	θ_1
55	θ_2
56	N
57	θ
58	δθ
59	K
0	
61	u
62	v
63	φ
64	L
65	Δ
66	ℓ
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

ALPHA

APPENDIX C:

PMPP CODE

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 1 OF 21

ROM'S 1 MATH BLOCK 2 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ]
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ]

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z	STORAGE	
0000	CNT					0050	1					b	
1	CNT					1	4					a	
2	CNT					2	0					0	
3	CNT					3	7					1	U_{min}
4	CNT					4	6					2	U_{max}
5	CLEAR		0	0	0	5	4					3	V_{min}
6	X←( )					6	6					4	V_{max}
7	0					7	9					5	
8	2					8	EEX					6	
9	1		H	0	0	9	9		μ	r^3	H	7	
0	FMT					0	X⇄Y		r^3	μ	H	8	
1	FMT					1	÷		r^3	μ/r^3	H	9	
2	A					2	↓		μ/r^3	H	H	10	T
3	L					3	$\sqrt{x}$		ω	H	H	11	x
4	T					4	X→( )					12	y
5	CNT					5	0					13	z
6	(					6	2					14	$\dot{x}$
7	N					7	0					15	$\dot{y}$
8	M					8	1					16	$\dot{z}$
9	)					9	6					17	f_x
0	CNT					0	0		160	H	H	18	f_y
1	=					1	X<Y					19	f_z
2	FMT					2	0					20	ω
3	$\boxed{\text{STOP}}$		H			NO 3	0					21	H
4	PRINT					4	9					22	W_s
5	PRINT					5	3					23	α_s
6	X→( )					6	.					24	$\dot{\alpha}_s$
7	0					7	0					25	ℓ
8	2					8	4					26	d
9	1					9	8					27	C_D
0	↑		H	H		0	5					28	W
1	↑		H	H	H	1	CHS		-.0485	H	H	29	α
2	3					2	X		-.0485	-.0485H	H	30	$\dot{\alpha}$
3	4					3	2					31	q
4	4					4	.					32	$\ell/2$
5	3					5	8					33	$d/2$
6	.					6	8		2.88	-.0485H	H	34	A_{SIDE}
7	9		3443.9	H	H	7	−		2.88	ln q	H	35	A_{END}
8	+		3443.9	R	H	8	GOTO					36	$\Delta\alpha_s$
9	6					9	0					37	$\Delta\alpha$
0	0					0	1					38	
1	7					1	3					39	
2	6					2	3					40	
3	.					0093	3					41	
4	1		6076.1	R	H	4	8					42	
5	X		6076.1	r	H	5	0		380	H	H	43	T_{STOP}
6	↓		r	H	H	6	X<Y					44	t
7	↑		r	r	H	7	0					45	ωt
8	X		r	r^2	H	NO 8	1					46	TEMP1
9	X		r	r^3	H	9	1					47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT)

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
0100	9				
1	.				
2	0				
3	3				
4	1				
5	4				
6	1				
7	CHS		-.03141	H	H
8	X		-.03141	-.03141H	H
9	5				
0	.				
1	6				
2	1		5.61	-.03141H	H
3	−		5.61	ln g	H
4	GO TO				
5	0				
6	1				
7	3				
8	3				
0119	.				
0	0				
1	1				
2	7				
3	5				
4	8				
5	CHS		-.01758	H	H
6	X		-.01758	-.01758H	H
7	1				
8	0				
9	.				
0	8				
1	7		10.87	-.01758H	H
2	−		10.87	ln g	H
0133	↓		ln g	H	H
4	J		g	H	H
5	X→( )				
6	0				
7	3				
8	1				
9	CLEAR		0	0	0
0	X←( )				
1	0				
2	2				
3	2		W_s	0	0
4	FMT				
5	FMT				
6	O				
7	R				
8	B				
9	CNT				

STEP	KEY	CODE	x	y	z
0150	W				
1	T				
2	CNT				
3	(				
4	L				
5	B				
6	)				
7	CNT				
8	=				
9	FMT				
0	$\boxed{\text{STOP}}$		W_s		
1	PRINT				
2	PRINT				
3	X→( )				
4	0				
5	2				
6	2				
7	GOTO				
8	SUB				
9	LBL				
0	5		α_s	0	0
1	$\boxed{\text{STOP}}$		α_s		
2	PRINT				
3	PRINT				
4	X→( )				
5	0				
6	2				
7	3				
8	CLEAR		0	0	0
9	X←( )				
0	0				
1	2				
2	4		$\dot{\alpha}_s$	0	0
3	FMT				
4	FMT				
5	O				
6	R				
7	B				
8	CNT				
9	P				
0	I				
1	T				
2	C				
3	H				
4	CNT				
5	R				
6	A				
7	T				
8	E				
9	CLEAR				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 3 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z	STORAGE	
0200	(					0250	CLEAR		0	0	0	b	
1	D					1	X←( )					a	
2	E					2	0					0	
3	G					3	2					1	U_{min}
4	/					4	6		d	0	0	2	U_{max}
5	S					5	FMT					3	V_{min}
6	E					6	FMT					4	V_{max}
7	C					7	P					5	
8	)					8	L					6	
9	CNT					9	CNT					7	
0	=					0	D					8	
1	FMT					1	I					9	
2	$\boxed{\text{STOP}}$		$\dot{\alpha}_s$			2	A					10	T
3	PRINT					3	CNT					11	x
4	PRINT					4	(					12	y
5	X→( )					5	F					13	z
6	0					6	T					14	$\dot{x}$
7	2					7	)					15	$\dot{y}$
8	4					8	CNT					16	$\dot{z}$
9	CLEAR		0	0	0	9	=					17	f_x
0	X←( )					0	FMT					18	f_y
1	0					1	$\boxed{\text{STOP}}$		d			19	f_z
2	2					2	PRINT					20	ω
3	5		ℓ	0	0	3	PRINT					21	H
4	FMT					4	X→( )					22	W_s
5	FMT					5	0					23	α_s
6	P					6	2					24	$\dot{\alpha}_s$
7	L					7	6					25	ℓ
8	CNT					8	CLEAR		0	0	0	26	d
9	L					9	X←( )					27	C_D
0	E					0	0					28	W
1	N					1	2					29	α
2	G					2	7		C_D	0	0	30	$\dot{\alpha}$
3	T					3	FMT					31	g
4	H					4	FMT					32	$\ell/2$
5	CNT					5	P					33	$d/2$
6	(					6	L					34	A_{SIDE}
7	F					7	CNT					35	A_{END}
8	T					8	C					36	$\Delta\alpha_s$
9	)					9	D					37	$\Delta\alpha$
0	CNT					0	CNT					38	
1	=					1	=					39	
2	FMT					2	FMT					40	
3	$\boxed{\text{STOP}}$		ℓ			3	$\boxed{\text{STOP}}$		C_D			41	
4	PRINT					4	PRINT					42	
5	PRINT					5	PRINT					43	T_{STOP}
6	X→( )					6	X→( )					44	t
7	0					7	0					45	ωt
8	2					8	2					46	TEMP1
9	5					9	7					47	TEMP2

ALPHA

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 4 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z
0300	CLEAR		0	0	0	0350	T				
1	X←( )					1	C				
2	0					2	H				
3	2					3	CNT				
4	8		W	0	0	4	R				
5	FMT					5	A				
6	FMT					6	T				
7	P					7	E				
8	L					8	CLEAR				
9	CNT					9	(				
0	W					0	D				
1	T					1	E				
2	CNT					2	G				
3	(					3	/				
4	L					4	S				
5	B					5	E				
6	)					6	C				
7	CNT					7	)				
8	=					8	CNT				
9	FMT					9	=				
0	STOP		W			0	FMT				
1	PRINT					1	STOP		$\dot{\alpha}$		
2	PRINT					2	PRINT				
3	X→( )					3	PRINT				
4	0					4	X→( )				
5	2					5	0				
6	8					6	3				
7	GOTO					7	0				
8	SUB					8	GOTO				
9	LBL					9	SUB				
0	4		α	0	0	0	LBL				
1	STOP		α			1	I		SEC	MIN	HR
2	PRINT					2	STOP		SEC	MIN	HR
3	PRINT					3	GOTO				
4	X→( )					4	SUB				
5	0					5	LBL				
6	2					6	J				
7	9					7	GOTO				
8	CLEAR		0	0	0	8	SUB				
9	X←( )					9	LBL				
0	0					0	a			T	
1	3					1	Y→( )				
2	0		$\dot{\alpha}$	0	0	2	0				
3	FMT					3	1				
4	FMT					4	0				
5	P					5	GOTO				
6	L					6	SUB				
7	CNT					7	LBL				
8	P					8	2		Z	Y	X
9	I					9	STOP		Z	Y	X

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0400	GOTO				
1	SUB				
2	LBL				
3	J				
4	X→( )				
5	0				
6	1				
7	3				
8	Y→( )				
9	0				
0	1				
1	2				
2	ROLL↑		X	Z	Y
3	X→( )				
4	0				
5	1				
6	1				
7	GOTO				
8	SUB				
9	LBL				
0	3		$\dot{z}$	$\dot{y}$	$\dot{x}$
1	$\boxed{\text{STOP}}$		$\dot{z}$	$\dot{y}$	$\dot{x}$
2	GOTO				
3	SUB				
4	LBL				
5	J				
6	X→( )				
7	0				
8	1				
9	6				
0	Y→( )				
1	0				
2	1				
3	5				
4	ROLL↑		$\dot{x}$	$\dot{z}$	$\dot{y}$
5	X→( )				
6	0				
7	1				
8	4				
9	X←( )				
0	0				
1	4				
2	3		T_{STOP}		
3	GOTO				
4	SUB				
5	LBL				
6	b		SEC	MIN	HR
7	FMT				
8	FMT				
9	T				

STEP	KEY	CODE	X	Y	Z
0450	S				
1	T				
2	O				
3	P				
4	CNT				
5	(				
6	H				
7	,				
8	M				
9	,				
0	S				
1	)				
2	CNT				
3	=				
4	FMT				
5	$\boxed{\text{STOP}}$		SEC	MIN	HR
6	GOTO				
7	SUB				
8	LBL				
9	J				
0	GOTO				
1	SUB				
2	LBL				
3	a			T_{STOP}	
4	Y→( )				
5	0				
6	4				
7	3				
8	X←( )				
9	0				
0	4				
1	4		t		
2	GOTO				
3	SUB				
4	LBL				
5	b		SEC	MIN	HR
6	FMT				
7	FMT				
8	D				
9	T				
0	CNT				
1	(				
2	H				
3	,				
4	M				
5	,				
6	S				
7	)				
8	CNT				
9	=				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT) NASA — MSC

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 6 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z
0500	FMT				
1	STOP		SEC	MIN	HR
2	GOTO				
3	SUB				
4	LBL				
5	J				
6	GOTO				
7	SUB				
8	LBL				
9	a			t	
0	Y→( )				
1	0				
2	4				
3	4				
4	2		2	t	
5	÷		2	t/2	
6	↓		t/2		
7	↑		t/2	t/2	
8	X←( )				
9	X				
0	0				
1	2				
2	4		$\Delta\alpha_s$	t/2	
3	Y⇄( )				
4	X				
5	0				
6	3				
7	0		$\Delta\alpha_s$	$\Delta\alpha$	
8	X→( )				
9	0				
0	3				
1	6				
2	Y→( )				
3	0				
4	3				
5	7				
6	X←( )				
7	0				
8	2				
9	6		d		
0	↑		d	d	
1	X←( )				
2	0				
3	2				
4	5		ℓ	d	
5	X		ℓ	ASIDE	
6	Y→( )				
7	0				
8	3				
9	4				

STEP	KEY	CODE	x	y	z
0550	↑		ℓ	ℓ	
1	.				
2	5		.5	ℓ	
3	X		.5	ℓ/2	
4	Y→( )				
5	0				
6	3				
7	2				
8	X←( )				
9	X				
0	0				
1	2				
2	6		d/2		
3	X→( )				
4	0				
5	3				
6	3				
7	X^2		$d^2/4$		
8	↑		$d^2/4$	$d^2/4$	
9	π		π	$d^2/4$	
0	X		π	AEND	
1	Y→( )				
2	0				
3	3				
4	5				
5	0		0		
6	X→( )				
7	0				
8	1				
9	8				
0	X→( )				
1	0				
2	1				
3	9				
4	CNT				
5	CNT				
6	CNT				
7	CNT				
8	CNT				
9	CNT				
0	CNT				
1	CNT				
2	CNT				
3	CNT				
4	CNT				
5	CNT				
6	CNT				
7	CNT				
8	CNT				
9	CNT				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	X
12	Y
13	Z
14	$\dot{X}$
15	$\dot{Y}$
16	$\dot{Z}$
17	f_X
18	f_Y
19	f_Z
20	ω
21	H
22	W_S
23	α_S
24	$\dot{\alpha}_S$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	q
32	ℓ/2
33	d/2
34	ASIDE
35	AEND
36	$\Delta\alpha_S$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	TSTOP
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0600	X←( )				
1	0				
2	3				
3	2		$\ell/2$		
4	CHS		$-\ell/2$		
5	↑		$-\ell/2$	$-\ell/2$	
6	X←( )				
7	0				
8	3				
9	3		$d/2$	$-\ell/2$	
0	GOTO				
1	SUB				
2	LBL				
3	π		U_1	V_1	
4	K				
5	FMT				
6	↑				
7	X←( )				
8	0				
9	3				
0	2		$\ell/2$		
1	↑		$\ell/2$	$\ell/2$	
2	X←( )				
3	0				
4	3				
5	3		$d/2$	$\ell/2$	
6	GOTO				
7	SUB				
8	LBL				
9	π		U_2	V_2	
0	K				
1	FMT				
2	↓				
3	X←( )				
4	0				
5	3				
6	2		$\ell/2$		
7	↑		$\ell/2$	$\ell/2$	
8	X←( )				
9	0				
0	3				
1	3		$d/2$	$\ell/2$	
2	CHS		$-d/2$	$\ell/2$	
3	GOTO				
4	SUB				
5	LBL				
6	π		U_3	V_3	
7	K				
8	FMT				
9	↓				

STEP	KEY	CODE	X	Y	Z
0650	X←( )				
1	0				
2	3				
3	2		$\ell/2$		
4	CHS		$-\ell/2$		
5	↑		$-\ell/2$	$-\ell/2$	
6	X←( )				
7	0				
8	3				
9	3		$d/2$	$-\ell/2$	
0	CHS		$-d/2$	$-\ell/2$	
1	GOTO				
2	SUB				
3	LBL				
4	π		U_4	V_4	
5	K				
6	FMT				
7	↓				
8	X←( )				
9	0				
0	3				
1	2		$\ell/2$		
2	CHS		$-\ell/2$		
3	↑		$-\ell/2$	$-\ell/2$	
4	X←( )				
5	0				
6	3				
7	3		$d/2$	$-\ell/2$	
8	GOTO				
9	SUB				
0	LBL				
1	π		U_1	V_1	
2	K				
3	FMT				
4	↓				
5	GOTO				
6	SUB				
7	LBL				
8	A				
9	CLEAR		0	0	0
0	X←( )				
1	0				
2	4				
3	3		TSTOP		
4	↑		TSTOP	TSTOP	
5	X←( )				
6	0				
7	1				
8	0		T	TSTOP	
9	X<Y				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	TSTOP
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT) NASA — MSC

PROGRAM NAME: PAYLOAD MOTION PLOT PROGRAM (PMPP)

PAGE 8 OF 21

ROM'S 1 MATH BLOCK 2 ________ 3 PRINTER ALPHA

EQUIPMENT NEEDED: [x] PRINTER [ ] MARKED CARD READER [x] PLOTTER [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036 — TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0700	0				
1	7				
2 (NO →)	0				
3	9				
4	GOTO				
5	0				
6	8				
7	8				
8	3				
0709	X←( )				
0	0				
1	2				
2	9		α_o		
3	↑		α_o	α_o	
4	X←( )				
5	0				
6	3				
7	7		$\Delta\alpha$	α_o	
8	+		$\Delta\alpha$	α'	
9	+		$\Delta\alpha$	α	
0	Y→( )				
1	0				
2	2				
3	9				
4	−		$\Delta\alpha$	α'	
5	1		1	α'	
6	B		$\cos\alpha'$	$\sin\alpha'$	
7	X^2		$\cos^2\alpha'$	$\sin\alpha'$	
8	$\sqrt{X}$		$\lvert\cos\alpha'\rvert$	$\sin\alpha'$	
9	X←( )				
0	X				
1	0				
2	3				
3	5		A'_{END}		
4	X⇄Y		$\sin\alpha'$	A'_{END}	
5	X^2		$\sin^2\alpha'$	A'_{END}	
6	$\sqrt{X}$		$\lvert\sin\alpha'\rvert$	A'_{END}	
7	X←( )				
8	X				
9	0				
0	3				
1	4		A'_{SIDE}	A'_{END}	
2	+		A'_{SIDE}	A	
3	X←( )				
4	0				
5	2				
6	7		C_D	A	
7	X		C_D	C_DA	
8	X←( )				
9	0				

STEP	KEY	CODE	X	Y	Z
0750	3				
1	1		g	C_DA	
2	X		g	D	
3	X←( )		g		
4	0				
5	2				
6	8		W	D	
7	÷		W	D/W	
8	X←( )				
9	0				
0	2				
1	3		α_{so}	D/W	
2	↑		α_{so}	α_{so}	D/W
3	X←( )				
4	0				
5	3				
6	6		$\Delta\alpha_s$	α_{so}	D/W
7	+		$\Delta\alpha_s$	α_s'	D/W
8	+		$\Delta\alpha_s$	α_s	D/W
9	Y→( )				
0	0				
1	2				
2	3				
3	−		$\Delta\alpha_s$	α_s'	D/W
4	↓		α_s'	D/W	D/W
5	M		$\sin\alpha_s'$	D/W	D/W
6	X^2		$\sin^2\alpha_s'$	D/W	D/W
7	$\sqrt{X}$		$\lvert\sin\alpha_s'\rvert$	D/W	D/W
8	↑		$\lvert\sin\alpha_s'\rvert$	$\lvert\sin\alpha_s'\rvert$	D/W
9	1				
0	.				
1	2				
2	0				
3	1				
4	2				
5	4		n	$\lvert\sin\alpha_s'\rvert$	D/W
6	X⇄Y		$\lvert\sin\alpha_s'\rvert$	n	D/W
7	H		$\lvert\sin\alpha_s'\rvert^n$	n	D/W
8	X⇄Y		n	$\lvert\sin\alpha_s'\rvert^n$	D/W
9	2				
0	.				
1	4				
2	6				
3	2				
4	0				
5	5		m	$\lvert\sin\alpha_s'\rvert^n$	D/W
6	X		m	$m\lvert\sin\alpha_s'\rvert^n$	D/W
7	.				
8	7				
9	2				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0800	1				
1	1				
2	5		.72115	m/[illegible]	D/W
3	+		.72115	C_{DS}	D/W
4	2				
5	6				
6	9				
7	0		2690	C_{DS}	D/W
8	X		2690	2690 C_{DS}	D/W
9	X←( )				
0	0				
1	3				
2	1		g	2690 C_{DS}	D/W
3	X		g	D_S	D/W
4	X←( )				
5	0				
6	2				
7	2		W_S	D_S	D/W
8	÷		W_S	D_S/W_S	D/W
9	↓		D_S/W_S	D/W	D/W
0	X⇄Y		D/W	D_S/W_S	D/W
1	−		D/W	Δ(D/W)	D/W
2	3				
3	2				
4	.				
5	1				
6	7				
7	4		32.174	Δ(D/W)	D/W
8	X		32.174	f_x	D/W
9	Y→( )				
0	0				
1	1				
2	7				
3	X←( )				
4	0				
5	4				
6	4		t		
7	↑			t	
8	GOTO				
9	SUB				
0	LBL				
1	•				
2	GOTO				
3	SUB				
4	LBL				
5	1		SEC	MIN	HR
6	GOTO				
7	SUB				
8	LBL				
9	J				

STEP	KEY	CODE	X	Y	Z
0850	GOTO				
1	SUB				
2	LBL				
3	2		Z	Y	X
4	GOTO				
5	SUB				
6	LBL				
7	J				
8	GOTO				
9	SUB				
0	LBL				
1	3		$\dot{Z}$	$\dot{Y}$	$\dot{X}$
2	GOTO				
3	SUB				
4	LBL				
5	J				
6	GOTO				
7	SUB				
8	LBL				
9	4		α	0	0
0	PRINT				
1	PRINT				
2	GOTO				
3	SUB				
4	LBL				
5	5		α_s	0	0
6	PRINT				
7	PRINT				
8	GOTO				
9	0				
0	6				
1	0				
2	0				
088 3	CLEAR		0	0	0
4	FMT				
5	↑				
6	$\boxed{\text{STOP}}$				
7	GOTO				
8	0				
9	0				
0	0				
1	0				
2					
3					
4					
5					
6					
7					
8					
9					

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
0900	LBL				
1	1				
2	X←( )				
3	0				
4	1				
5	0		T		
6	GOTO				
7	SUB				
8	LBL				
9	b		SEC	MIN	HR
0	FMT				
1	FMT				
2	T				
3	I				
4	M				
5	E				
6	CNT				
7	(				
8	H				
9	,				
0	M				
1	,				
2	S				
3	)				
4	CNT				
5	=				
6	FMT				
7	RETURN				
0928	LBL				
9	2				
0	X←( )				
1	0				
2	1				
3	1		X		
4	↑		X	X	
5	X←( )				
6	0				
7	1				
8	2		Y	X	
9	↑		Y	Y	X
0	X←( )				
1	0				
2	1				
3	3		Z	Y	X
4	FMT				
5	FMT				
6	P				
7	L				
8	CNT				
9	P				

STEP	KEY	CODE	X	Y	Z
0950	O				
1	S				
2	CNT				
3	(				
4	F				
5	T				
6	)				
7	CNT				
8	=				
9	FMT				
0	RETURN				
0961	LBL				
2	3				
3	X←( )				
4	0				
5	1				
6	4		$\dot{x}$		
7	↑		$\dot{x}$	$\dot{x}$	
8	X←( )				
9	0				
0	1				
1	5		$\dot{y}$	$\dot{x}$	
2	↑		$\dot{y}$	$\dot{y}$	$\dot{x}$
3	X←( )				
4	0				
5	1				
6	6		$\dot{z}$	$\dot{y}$	$\dot{x}$
7	FMT				
8	FMT				
9	P				
0	L				
1	CNT				
2	V				
3	E				
4	L				
5	CNT				
6	(				
7	F				
8	P				
9	S				
0	)				
1	CNT				
2	=				
3	FMT				
4	RETURN				
0995	LBL				
6	4				
7	CLEAR		0	0	0
8	X←( )				
9	0				

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	q
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

NASA — MS

MSC Form 1178 (Jun 72) (OT)

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 11 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
1000	2				
1	9		α	0	0
2	FMT				
3	FMT				
4	P				
5	L				
6	CNT				
7	P				
8	I				
9	T				
0	C				
1	H				
2	CNT				
3	(				
4	D				
5	E				
6	G				
7	)				
8	CNT				
9	=				
0	FMT				
1	RETURN				
1022	LBL				
3	5				
4	CLEAR		0	0	0
5	X←( )				
6	0				
7	2				
8	3		α_s	0	0
9	FMT				
0	FMT				
1	O				
2	R				
3	B				
4	CNT				
5	P				
6	I				
7	T				
8	C				
9	H				
0	CNT				
1	(				
2	D				
3	E				
4	G				
5	)				
6	=				
7	FMT				
8	RETURN				
9	CNT				

STEP	KEY	CODE	X	Y	Z
1050	LBL				
1	A				
2	FMT				
3	FMT				
4	*				
5	*				
6	*				
7	*				
8	*				
9	*				
0	*				
1	*				
2	*				
3	*				
4	*				
5	*				
6	*				
7	*				
8	*				
9	*				
0	CLEAR				
1	CLEAR				
2	FMT				
3	RETURN				
1074	LBL				
5	a		SEC	MIN	HR
6	X→( )				
7	a				
8	↓		MIN	HR	HR
9	X⇄Y		HR	MIN	HR
0	↑		HR	HR	MIN
1	6				
2	0		60	HR	MIN
3	×		60	MIN'	MIN
4	↓		MIN'	MIN	MIN
5	+		MIN'	MIN''	
6	6				
7	0		60	MIN''	
8	×		60	SEC''	
9	X←( )				
0	a		SEC	SEC''	
1	+			T	
2	RETURN				
1093	LBL				
4	b		T		
5	X→( )				
6	b				
7	↑		T	T	
8	3				
9	6				

STORAGE	
b	T
a	SEC
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	ASIDE
35	AEND
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
1100	0				
1	0		3600	T	
2	÷		3600	T/3600	
3	X⇌Y		T/3600	3600	
4	int X		HR	3600	
5	X		HR	3600 HR	
6	X⇌Y		3600 HR	HR	
7	CHS		-3600 HR	HR	
8	↑		-3600 HR	-3600 HR	HR
9	X←()				
0	b		T	-3600 HR	HR
1	+		T	T'	HR
2	Y→()				
3	b				
4	6				
5	0		60	T'	HR
6	÷		60	T'/60	HR
7	X⇌Y		T'/60	60	HR
8	int X		MIN	60	HR
9	X		MIN	60 MIN	HR
0	X⇌Y		60 MIN	MIN	HR
1	CHS		-60 MIN	MIN	HR
2	X←()				
3	+				
4	b		SEC	MIN	HR
5	RETURN				
1126	LBL				
7	J		Z	Y	X
8	ROLL↑		X	Z	Y
9	PRINT				
0	ROLL↑		Y	X	Z
1	PRINT				
2	ROLL↑		Z	Y	X
3	PRINT				
4	PRINT				
5	RETURN				
1136	LBL				
7	π		Z_{PB}	X_{PB}	
8	F		R	θ_0	
9	Y⇌()				
0	+				
1	0				
2	2				
3	9		R	θ	
4	B		ΔZ	ΔX	
5	X←()				
6	+				
7	0				
8	1				
9	3		Z'	ΔX	

STEP	KEY	CODE	X	Y	Z
1150	Y⇌()				
1	+				
2	0				
3	1				
4	1		Z'	X'	
5	F		R'	θ_0'	
6	Y⇌()				
7	−				
8	0				
9	2				
0	3		R'	θ'	
1	B		-ΔV'	-ΔU'	
2	↑		-ΔV'	-ΔV'	-ΔU'
3	1				
4	2				
5	CHS		-12	-ΔV'	-ΔU'
6	X		-12	ΔV	-ΔU'
7	ROLL↑		-ΔU'	-12	ΔV
8	X		-ΔU'	ΔU	ΔV
9	1				
0	0				
1	9				
2	3		1093	ΔU	ΔV
3	+		1093	U	ΔV
4	3				
5	8				
6	0		380	U	ΔV
7	ROLL↑		ΔV	380	U
8	+		ΔV	V	U
9	X⇌Y		V	ΔV	U
0	ROLL↑		U	V	
1	RETURN				
2					
3					
4					
5					
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					

STORAGE	
b	T, T'
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	X
12	Y
13	Z
14	$\dot{X}$
15	$\dot{Y}$
16	$\dot{Z}$
17	f_X
18	f_Y
19	f_Z
20	ω
21	H
22	W_S
23	α_S
24	$\dot{\alpha}_S$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	ℓ/2
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_S$
37	Δα
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

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MSC Form 1178 (Jun 72) (OT)

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 13 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [ ] ______
- [x] PLOTTER
- [ ] TYPEWRITER
- [ ] ______

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE				STEP	KEY	CODE				STORAGE	
1200						1250						b	
1						1						a	
2						2						0	
3						3						1	U_{min}
4						4						2	U_{max}
5						5						3	V_{min}
6						6						4	V_{max}
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						10	T
3						3						11	X
4						4						12	Y
5						5						13	Z
6						6						14	$\dot{X}$
7						7						15	$\dot{Y}$
8						8						16	$\dot{Z}$
9						9						17	f_X
0						0						18	f_Y
1						1						19	f_Z
2						2						20	ω
3						3						21	H
4						4						22	W_S
5						5						23	α_S
6						6						24	$\dot{\alpha}_S$
7						7						25	ℓ
8						8						26	d
9						9						27	C_D
0						0						28	W
1						1						29	α
2						2						30	$\dot{\alpha}$
3						3						31	g
4						4						32	$\ell/2$
5						5						33	$d/2$
6						6						34	A_{SIDE}
7						7						35	A_{END}
8						8						36	$\Delta\alpha_S$
9						9						37	$\Delta\alpha$
0						0						38	
1						1						39	
2						2						40	
3						3						41	
4						4						42	
5						5						43	T_{STOP}
6						6						44	t
7						7						45	ωt
8						8						46	TEMP1
9						9						47	TEMP2

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MSC Form 1178 (Jun 72) (OT) NASA — MSC

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 14 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z
1300						1350					

STORAGE	
b	
a	
0	
1	Umin
2	Umax
3	Vmin
4	Vmax
5	
6	
7	
8	
9	
10	T
11	X
12	Y
13	Z
14	$\dot{X}$
15	$\dot{Y}$
16	$\dot{Z}$
17	fx
18	fy
19	fz
20	ω
21	H
22	Ws
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	Cp
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	d/2
34	ASIDE
35	AEND
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	TSTOP
44	t
45	ωt
46	TEMP1
47	TEMP2

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MSC Form 1178 (Jun 72) (OT)

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 15 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z
1400						1450					

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	X
12	Y
13	Z
14	$\dot{X}$
15	$\dot{Y}$
16	$\dot{Z}$
17	f_X
18	f_Y
19	f_Z
20	ω
21	H
22	W_S
23	α_S
24	$\dot{\alpha}_S$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_S$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT) NASA — MSC

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z
1500						1550					
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					
0						0					
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					
0						0					
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					
0						0					
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					
0						0					
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	X
12	Y
13	Z
14	$\dot{X}$
15	$\dot{Y}$
16	$\dot{Z}$
17	f_X
18	f_Y
19	f_Z
20	ω
21	H
22	W_S
23	α_S
24	$\dot{\alpha}_S$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_S$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OF)

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	x	y	z	STEP	KEY	CODE	x	y	z	STORAGE	
1600						1650						b	
1						1						a	
2						2						0	
3						3						1	U_{min}
4						4						2	U_{max}
5						5						3	V_{min}
6						6						4	V_{max}
7						7						5	
8						8						6	
9						9						7	
0						0						8	
1						1						9	
2						2						10	T
3						3						11	x
4						4						12	y
5						5						13	z
6						6						14	$\dot{x}$
7						7						15	$\dot{y}$
8						8						16	$\dot{z}$
9						9						17	f_x
0						0						18	f_y
1						1						19	f_z
2						2						20	ω
3						3						21	H
4						4						22	W_s
5						5						23	α_s
6						6						24	$\dot{\alpha}_s$
7						7						25	l
8						8						26	d
9						9						27	C_D
0						0						28	W
1						1						29	α
2						2						30	$\dot{\alpha}$
3						3						31	g
4						4						32	$l/2$
5						5						33	$d/2$
6						6						34	A_{SIDE}
7						7						35	A_{END}
8						8						36	$\Delta\alpha_s$
9						9						37	$\Delta\alpha$
0						0						38	
1						1						39	
2						2						40	
3						3						41	
4						4						42	
5						5						43	T_{STOP}
6						6						44	t
7						7						45	ωt
8						8						46	TEMP1
9						9						47	TEMP2

ALPHA

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
1700					
1					
2					
3					
4					
5					
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					

STEP	KEY	CODE	X	Y	Z
1750	LBL				
1	•			t	
2	Y→( )				
3	t				
4	0				
5	1				
T 6	0				
7	X←( )				
8	0				
9	2				
0	0		ω	t	
1	X		ω	ωt	
2	Y→( )				
3	0				
4	4				
5	5				
6	K				
7	2				
8	↑		ω	ω	ωt
9	1/X		1/ω	ω	
0	Y⇄( )				
1	X				
2	0				
3	1				
4	2		1/ω	ωY_0	
5	X←( )				
6	X				
7	0				
8	1				
9	8		f_y/ω	ωY_0	
0	−		f_y/ω	X_0	
1	↑		f_y/ω	f_y/ω	X_0
2	X←( )				
3	0				
4	1				
5	5		$\dot{y}_0 = Y_0$	f_y/ω	X_0
6	ROLL↑		X_0	Y_0	f_y/ω
7	F		R	θ_0	f_y/ω
8	Y⇄( )				
9	−				
0	0				
1	4				
2	5		R	θ	f_y/ω
3	B		X	$Y = \dot{y}$	f_y/ω
4	Y→( )				
5	0				
6	1				
$\dot{y}$ 7	5				
8	ROLL↑		f_y/ω	X	$\dot{y}$
9	+		f_y/ω	ωY	

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	ℓ/2
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	Δα
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

MSC Form 1178 (Jun 72) (OT)

NASA — MSC

ROM'S 1 MATH BLOCK 2 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER [ ] MARKED CARD READER [ ]
- [x] PLOTTER [ ] TYPEWRITER [ ]

TOTAL PROGRAM STEPS [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
1800	X←()				
1	0				
2	2				
3	0		ω	ωY	
4	÷		ω	Y	
5	Y→()				
6	0				
7	1				
Y 8	2				
9	↑		ω	ω	Y
0	CHS		-ω	ω	
1	↑		-ω	-ω	ω
2	3		3	-ω	ω
3	X		3	-3ω	ω
4	X←()				
5	0				
6	1				
7	3		Z_0	-3ω	ω
8	X		Z_0	$-3\omega Z_0$	ω
9	2		2	$-3\omega Z_0$	ω
0	X←()				
1	X				
2	0				
3	1				
4	4		$2\dot{X}_0$	$-3\omega Z_0$	ω
5	+		$2\dot{X}_0$	$2\dot{X}_0-3\omega Z_0$	ω
6	X⇄Y		$2\dot{X}_0-3\omega Z_0$	$2\dot{X}_0$	ω
7	ROLL↑		ω	$2\dot{X}_0-3\omega Z_0$	$2\dot{X}_0$
8	1/X		1/ω	$2\dot{X}_0-3\omega Z_0$	
9	X←()				
0	X				
1	0				
2	1				
3	9		f_z/ω	$2\dot{X}_0-3\omega Z_0$	
4	−		f_z/ω	X_0	
5	Y→()				
6	a				
7	X←()				
8	0				
9	1				
0	6		$\dot{Z}_0$	X_0	
1	↑		$\dot{Z}_0$	$\dot{Z}_0$	X_0
2	X←()				
3	0				
4	1				
5	7		f_x	$\dot{Z}_0$	X_0
6	X←()				
7	÷				
8	0				
9	2				

STEP	KEY	CODE	X	Y	Z
1850	0		f_x/ω	$\dot{Z}_0$	X_0
1	+		f_x/ω	$\dot{Z}_0+f_x/\omega$	X_0
2	+		f_x/ω	Y_0	X_0
3	ROLL↑		X_0	f_x/ω	Y_0
4	ROLL↑		Y_0	X_0	f_x/ω
5	X⇄Y		X_0	Y_0	f_x/ω
6	F		R	θ_0	f_x/ω
7	Y⇄()				
8	−				
9	0				
0	4				
1	5		R	θ	f_x/ω
2	B		X	Y	f_x/ω
3	X⇄Y		Y	X	f_x/ω
4	ROLL↑		f_x/ω	Y	X
5	−		f_x/ω	$\dot{Z}+f_x/\omega$	
6	−		f_x/ω	$\dot{Z}$	X
7	X←()				
8	X				
9	0				
0	4				
1	5		$f_x t$	$\dot{Z}$	X
2	X→()				
3	&				
4	ROLL↑		X	$f_x t$	$\dot{Z}$
5	X⇄Y		$f_x t$	X	$\dot{Z}$
6	−		$f_x t$	$X-f_x t$	$\dot{Z}$
7	−		$f_x t$	$X-2f_x t$	$\dot{Z}$
8	X←()				
9	a		X_0	$X-2f_x t$	$\dot{Z}$
0	−		X_0	$\omega(Z-Z_0)$	$\dot{Z}$
1	↓		$\omega(Z-Z_0)$	$\dot{Z}$	$\dot{Z}$
2	↑		$\omega(Z-Z_0)$	$\omega(Z-Z_0)$	$\dot{Z}$
3	+		$\omega(Z-Z_0)$	$2\omega(Z-Z_0)$	$\dot{Z}$
4	X←()				
5	÷				
6	0				
7	2				
8	0		$Z-Z_0$	$2\omega(Z-Z_0)$	$\dot{Z}$
9	X→()				
0	+				
1	0				
2	1				
Z 3	3				
4	↓		$2\omega(Z-Z_0)$	$\dot{Z}$	$\dot{Z}$
5	Y⇄()				
6	−				
7	0				
8	1				
9	6		$2\omega(Z-Z_0)$	$Z-Z_0$	$\dot{Z}$

STORAGE	
b	$f_x t$
a	X_0
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_D
28	W
29	α
30	$\dot{\alpha}$
31	g
32	ℓ/2
33	d/2
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	Δα
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA

PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP)

ROM'S 1 MATH BLOCK 2 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z	STEP	KEY	CODE	X	Y	Z	STORAGE	
1900	ROLL↑		$\dot{z}$	$2\omega(z-z_0)$	$\dot{z}-\dot{z}_0$	1950	2					b	fxt
1	X→( )					1	0		ω	$\omega(X-X_0)$		a	$\bar{X}_0$
2	0					2	÷		ω	$X-X_0$		0	
3	1					3	Y→( )					1	U_{min}
$\dot{z}$ 4	6					4	+					2	U_{max}
5	X←( )					5	0					3	V_{min}
6	b		fxt	$2\omega(z-z_0)$	$\dot{z}-\dot{z}_0$	6	1					4	V_{max}
7	+		fxt	$\dot{x}-\dot{x}_0$	$\dot{z}-\dot{z}_0$	x 7	1					5	
8	X←( )					8	K					6	
9	0					9	1					7	
0	1					0	RETURN					8	
1	4		$\dot{x}_0$	$\dot{x}-\dot{x}_0$	$\dot{z}-\dot{z}_0$	1						9	
2	+		$\dot{x}_0$	$\dot{x}$	$\dot{z}-\dot{z}_0$	2						10	T
3	Y→( )					3						11	x
4	0					4						12	y
5	1					5						13	z
$\dot{x}$ 6	4					6						14	$\dot{x}$
7	X←( )					7						15	$\dot{y}$
8	X					8						16	$\dot{z}$
9	0					9						17	f_x
0	4					0						18	f_y
1	5		$\dot{x}_0\omega t$	$\dot{x}$	$\dot{z}-\dot{z}_0$	1						19	f_z
2	ROLL↑		$\dot{z}-\dot{z}_0$	$\dot{x}_0\omega t$	$\dot{x}$	2						20	ω
3	↑		$\dot{z}-\dot{z}_0$	$\dot{z}-\dot{z}_0$	$\dot{x}_0\omega t$	3						21	H
4	X←( )					4						22	W_s
5	a		$\bar{X}_0$	$\dot{z}-\dot{z}_0$	$\dot{x}_0\omega t$	5						23	α_s
6	X←( )					6						24	$\dot{\alpha}_s$
7	X					7						25	ℓ
8	0					8						26	d
9	4					9						27	C_D
0	5		$\bar{X}_0\omega t$	$\dot{z}-\dot{z}_0$	$\dot{x}_0\omega t$	0						28	W
1	+		$\bar{X}_0\omega t$	[ ]	$\dot{x}_0\omega t$	1						29	α
2	2		2	[ ]	$\dot{x}_0\omega t$	2						30	$\dot{\alpha}$
3	X		2	2[ ]	$\dot{x}_0\omega t$	3						31	q
4	↓		2[ ]	$\dot{x}_0\omega t$	$\dot{x}_0\omega t$	4						32	$\ell/2$
5	−		2[ ]	$\dot{x}_0\omega t-2[\ ]$		5						33	$d/2$
6	1					6						34	A_{SIDE}
7	.					7						35	A_{END}
8	5		1.5	$\dot{x}_0\omega t-2[\ ]$		8						36	$\Delta\alpha_s$
9	X←( )					9						37	$\Delta\alpha$
0	X					0						38	
1	b		$1.5fxt$	$\dot{x}_0\omega t-2[\ ]$		1						39	
2	X←( )					2						40	
3	X					3						41	
4	0					4						42	
5	4					5						43	T_{STOP}
6	5		$1.5\omega t^2 f_x$	$\dot{x}_0\omega t-2[\ ]$		6						44	t
7	−		$1.5\omega t^2 f_x$	$\omega(X-X_0)$		7						45	ωt
8	X←( )					8						46	TEMP1
9	0					9						47	TEMP2

ALPHA

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PROGRAM NAME PAYLOAD MOTION PLOT PROGRAM (PMPP) PAGE 21 OF 21

ROM'S 1 MATH BLOCK 2 ______ 3 PRINTER ALPHA

EQUIPMENT NEEDED

- [x] PRINTER
- [ ] MARKED CARD READER
- [x] PLOTTER
- [ ] TYPEWRITER

TOTAL PROGRAM STEPS: [ ] 500 [ ] 1012 [x] 2036

TOTAL REGISTERS: [ ] 51 [x] 111

STEP	KEY	CODE	X	Y	Z
2000					
1					
2					
2003	LBL				
4	F		X	Y	Z
5	ROLL↑		Z	X	Y
6	X→( )				
7	0				
8	4				
9	7				
0	↓		X	Y	Y
1	A		R	θ_0	
2	X⇄Y		θ_0	R	
3	X→( )				
4	0				
5	4				
6	6				
7	0		0	R	
8	X=Y				
9	X→( )				
NO 0	0				
1	4				
2	6				
3	X←( )				
4	0				
5	4				
6	6		θ_0	R	
7	↑		θ_0	θ_0	R
8	X←( )				
9	0				
0	4				
1	7		Z	θ_0	R
2	X⇄Y		θ_0	Z	R
3	ROLL↑		R	θ_0	Z
4	RETURN				
5	END				
6					
7					
8					
9					
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					

STORAGE	
b	
a	
0	
1	U_{min}
2	U_{max}
3	V_{min}
4	V_{max}
5	
6	
7	
8	
9	
10	T
11	x
12	y
13	z
14	$\dot{x}$
15	$\dot{y}$
16	$\dot{z}$
17	f_x
18	f_y
19	f_z
20	ω
21	H
22	W_s
23	α_s
24	$\dot{\alpha}_s$
25	ℓ
26	d
27	C_p
28	W
29	α
30	$\dot{\alpha}$
31	q
32	$\ell/2$
33	$d/2$
34	A_{SIDE}
35	A_{END}
36	$\Delta\alpha_s$
37	$\Delta\alpha$
38	
39	
40	
41	
42	
43	T_{STOP}
44	t
45	ωt
46	TEMP1
47	TEMP2

ALPHA